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FINAL REPORT

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THE ROLE OF SHELL MATERIAL IN THE NATURAL SAND REPLENISHMENT CYCLE OF THE BEACH AND NEARSHORE AREA BETWEEN LAKE WORTH INLET AND THE MIAMI SHIP CHANNEL

Submitted to:
Coastal Engineering Research Center
U. S. Army Corps of Engineers
(DA-49-055-CIV-ENG-63-12)

MIAMI, FLORIDA

INSTITUTE OF MARINE SCIENCE

The Marine Laboratory
University of Miami

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THE ROLE OF SHELL MATERIAL IN THE NATURAL SAND REPLENISHMENT CYCLE OF THE BEACH AND NEARSHORE AREA BETWEEN LAKE WORTH INLET AND THE MIAMI SHIP CHANNEL

By

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ABSTRACT

Study of beach-face and foredune sand samples, collected at intervals of approximately 8 nautical miles over a total distance of 277 nautical miles of beach, was made in an effort to evaluate the sand replenishment cycle. The methods used for the study included grain-size determinations, mineralogic examination of shells and other constituents by x-ray diffraction and optical techniques, standard paleontologic examination of shell assemblages, and assays of contained radiocarbon activity.

A variable but systematic increase in shell material prevails from near the St. Johns River at Jacksonville to Bear Cut at Miami. The percentage of shell, determined by acid digestion, increases from a low of about 2% by wt. near Jacksonville to a high of 89% near Boca Raton Inlet. If one excludes widely divergent values from the general trend, then the average shell content in wt. percentage increases from about 10% at Jacksonville to about 65% at Miami; i.e., an average rate of increase of approximately 0.2% per mile. Widely divergent values from this general trend may be attributed to an immediate source of relatively carbonate-poor "older" dune sands or relatively carbonate-rich inlets whose environment is conducive to a high standing crop of shelled organisms.

Abrasion tests in tumbling barrels show comparatively little loss of shell during 600 miles of linear distance traveled in bed-load transport. Abrasion over this calculated distance was so slight (1.2% by wt.) as to be unrecognizable by changes in grain-size distribution as determined by sieving (note Appendix C). It may be concluded also that impact conditions within the tumbling barrel apparently were insufficient to break-up shell fragments by fracturing. Thus, if shell fracturing is significant on a natural beach that mechanism may degenerate shell content. However, absence of freshly fractured shells in the microscopic examination of natural shell fragments suggests abrasive polishing is the dominant mode of size reduction rather than fracture.

Paleontologic study of shell materials in the beach samples failed to provide a confident mode of distinguishing fresh contemporaneous shell contributions (by standing crops) from those contributions of shell which were derived from erosion of "old" deposits making up local substrate. Mineralogic composition of the total shell fraction also failed to be sufficiently variable to assure distinction between modern shell fragments and ancient shell fragments. Thus, neither paleontologic nor mineralogic criteria could be used with relative precision in judging the fractional contribution of "new" and "old" shell to the beach replenishment cycle.

Radiocarbon assay of the carbonate fraction of the beach materials demonstrates radioactivity values intermediate between modern shell and "radioactively-dead" ancient shells being derived from outcrops of Pleistocene Anastasia coquina. The values obtained by radiocarbon assay suggest that as little as about 20% of the shell in the area near Cape Kennedy is new shell, but near Miami as much as 50 to 60% of the total

may be new shell. Inlet areas such as Fort Pierce or Lake Worth can have as much as 70% of the shell derived from a modern source. Inlet areas have a particularly high standing crop of shell forms and thus contribute a higher percentage of shell than a normal beach.

It may be concluded that relatively little shell is being contributed to the northern beaches of Florida either by erosion of "older" deposits or contributions from contemporaneous sources. Beaches of South Florida in the vicinity of Lake Worth to Miami receive relatively little quartz sands from northern flood plains and apparently derive equal amounts of shell from old deposits and from contemporaneous sources.

Loss of sand from the beaches of South Florida near Lake Worth to Miami may be attributed in part to inlet capture of replenishment sand by tidal currents, but discounting the estimated capture by inlets still leaves substantial losses of beach sand to other processes. The evidence for loss to inlets is found in the development of tidal deltas within bays and sounds and in the silting-up of these bays. Apparently, the unaccounted for sand loss is attributable to the spilling of sand off the narrow shelf and loss to deep water. Evidence of a large lense of sand on the floor of the adjacent Florida Straits indicates that much sand has spilled into the Straits from such a local source. The steep erosive waves generated during the winter months move beach sand seaward along the shelf. Long period summer waves generated in the central and south Atlantic cannot move sand shoreward again because of the protection of the Florida shore here by the Bahama islands. However, even without the effective shadow of the Bahamas the net loss to deep water would be relatively high because of the narrow shelf and lack of sand source to the south. Artificial nourishment of beaches here seems to be the single most direct solution to maintaining them.

INTRODUCTION

The problem of beach erosion and shoreline recession has been particularly acute along the valuable frontage properties lying between Martin and Dade Counties, Florida (U. S. Army Corps of Engineers, 1963). Few other areas along Florida's extensive coastline seem to suffer such extensive destruction (see for example also Bruun and Manohar, 1963). The area has therefore been the subject of intensive study; especially into those characteristics which distinguish this section of southeast Florida from beaches further to the north (Figure 1).

The east coast of Florida represents an extensive series of sand barriers built up on the gradually-seaward-sloping surface of pre-existing sediments. These barriers undoubtedly formed by the same glacially controlled transgressive processes which were responsible for the development of other coastal barriers, such as those along the southeast Texas coast (Rusnak, 1960; Sheperd, 1960; Curray, 1960; Bernard et al, 1962). The most extensive barrier complex is developed at Cape Kennedy

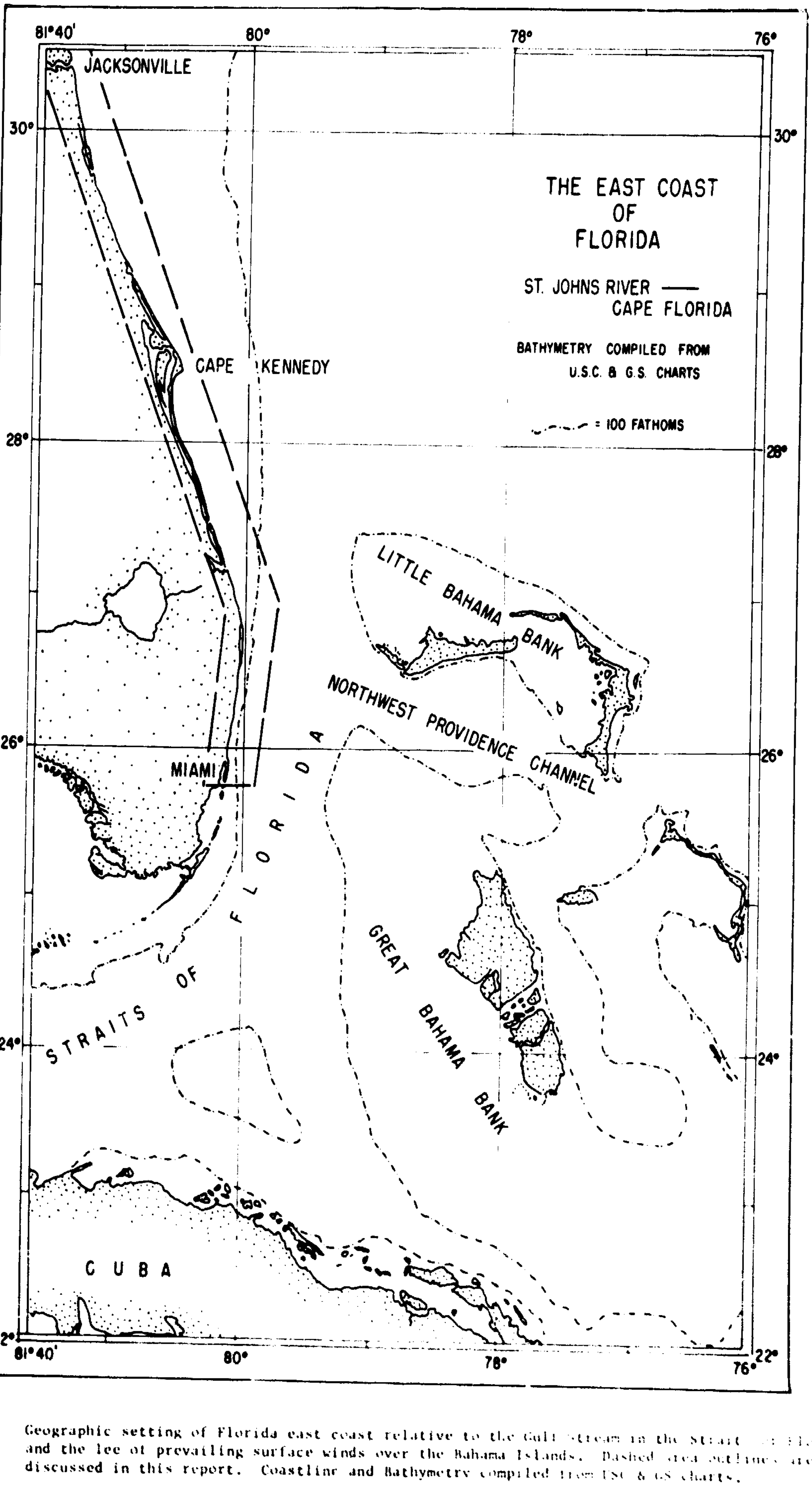

Figure 1. Geographic setting of Florida east coast relative to the Gulf Stream in the Strait of Florida and the lee of prevailing surface winds over the Bahama Islands. Dashed area outlines area discussed in this report. Coastline and Bathymetry compiled from USC & GS charts.

(Kofoed, 1963). Barrier-width varies considerably but the height seldom exceeds 25 feet. Some barrier migration has occurred during historical times, but mostly the present geographic positions seem to have been stabilized shortly after their growth and development at the close of the last major glaciation ending some 5,000 years ago.

Throughout the greater part of the Florida east coast, the barrier sands cover Late Pleistocene coquina deposits of the Anastasia formation (Cooke, 1945) typified on Anastasia Island (plate 1). These underlying partially-consolidated deposits form the backbone of the barriers and outcrop as coquina reefs as much as one-half mile or more offshore. In places the coquina appears to have furnished a large volume of shell fragments to the barrier through the disintegration of the outcrops by wave erosion. Martens (1935) has demonstrated that, with the exception of shell, the minerals found in the Florida beach sands are derived by southward transport form eroded rocks of the Piedmont far to the north. The U. S. Army Corps of Engineers has clearly established this fact in measured average annual southerly drift rates of beach materials. Seasonal study of wave and swell data indicate that during September through February the prevailing and predominant swells approach from directions which set up southerly drift; during March to April the drift directions are uncertain; and during June through August the drift is northerly. It is significant that the continental shelf width is relatively constant from just south of Cape Hatteras to about the latitude of Jacksonville, where the shelf narrows rapidly and uniformly from about 60 miles to about 2.5 miles off Palm Beach, Florida (figure 2), where large losses of beach material prevail. This narrowing of the shelf is believed by the present writers to be structurally controlled as an area of positive motions relative to the areas both north and south.

The studies of the U. S. Army Corps of Engineers (1963) have shown that a gross loss of 786,000 (586,000 excluding inlets) cubic yards of beach materials disappear from the beach regime each year along the segment of the coast between Lake Worth Inlet and Government Cut at Miami. The beach materials here are dominated by shell sands or sands with a high shell content. Shells therefore constitute an important element of the sand supply. These beach materials are apparently lost from the littoral zone as they are not found in: (1) the nearshore zone shoreward of the 30-foot contour; (2) the estuaries and channel entrances which connect with the shore; or (3) the zone seaward of the 30-foot contour where samples have been collected. Inshore of the 30-foot contour sampling is less extensive and therefore less clear.

Although the degree of shoreline erosion is relatively well known, the details of the various depletionary factors involved are only poorly known and the methods for their control are therefore difficult ones. The erosion problem is a continuing one requiring that some steps be taken to supply new material to the beaches to balance the presently unchecked loss rate (U. S. Army Corps of Engineers, 1963). A complete investigation of the littoral environment is necessary if

the beach erosion problems are to be alleviated by possible capture of lost sand and by effective beach preservation measures. Included in such an investigation would be a study of the composition of the littoral materials, the forces acting upon them, and their transport. The sources of the individual sedimentary components should be considered to determine the residence time, and removal of these components as beach forming materials either by disintegration or loss to deep water.

The immediate primary objective of the present study was to investigate the role of natural shell replenishment as a contributing element in the nourishment of beach material along the beach and nearshore area lying between Lake Worth Inlet and the Miami Ship Channel. In particular, it was important to determine the kind and amount of shell being contributed to this area. It was not known whether the shell material contributed is largely, or only in part, eroded outcrop from the Anastasia and related formations or whether it is mostly fresh shell contributed annually to the local supply.

Recognition and quantitative evaluation of the relative proportions of old and new shell in the beaches from these two sources can spell the difference in providing for successful control of beach erosion problems. Moreover, it can provide that necessary insight which is required by theoretical considerations of beach development where "shell" forms a substantial part of the sediment.

Preliminary considerations of the problem

The fundamental questions raised in the present study have been raised by many students of beach cycles in determining materal loss and nourishment of the beaches:

(1) Is the present beach shell composed of recent shell or old shell, or, if both, in what proportions?

(2) If this is new shell, at what rate is the shell coming into existence to replenish the beaches and how does it reach the beach face?

(3) If this is old shell, is the source offshore, from the eroded beach face, or from the weathering of the coquina outcroppings in the area?

(4) In what way is the beach shell lost to the beaches at the present high rate--by dissolving into the sea water, by grinding into fine detritus and being carried off in suspension, or by moving along the bottom in alongshore drift and being lost to deep offshore water at a narrow point of the shelf, or is it drifting laterally offshore?

(5) Is there any indication that the silica sand component of the beach tends to remain on the beach longer than the shell?

NOT REPRODUCIBLE

PLATE 1 Outcrop of typical coquina limestone which forms the backbone of many islands along the eastcoast of Florida. This example is from the type section of the Anastasia fm. on Anastasia Island.

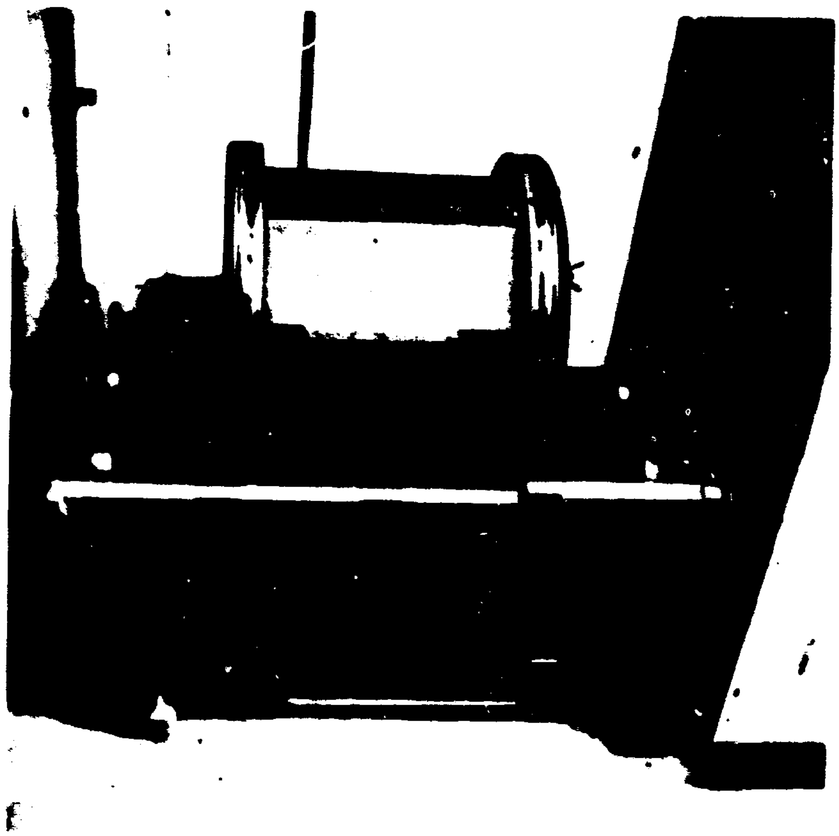

PLATE 2 Octagonal-shaped tumbling barrel used in experimental study of shell-sand abrasion. The tumbling barrel (Sears, Roebuck & Co. Heavy Duty Model) has a nominal diameter of 8.9 inches to comprise a 28 inch circumference consisting of eight 3.5 inch straight segments. A 1/3 h.p. electric motor provided a rotational speed of 41.4 revolutions per minute.

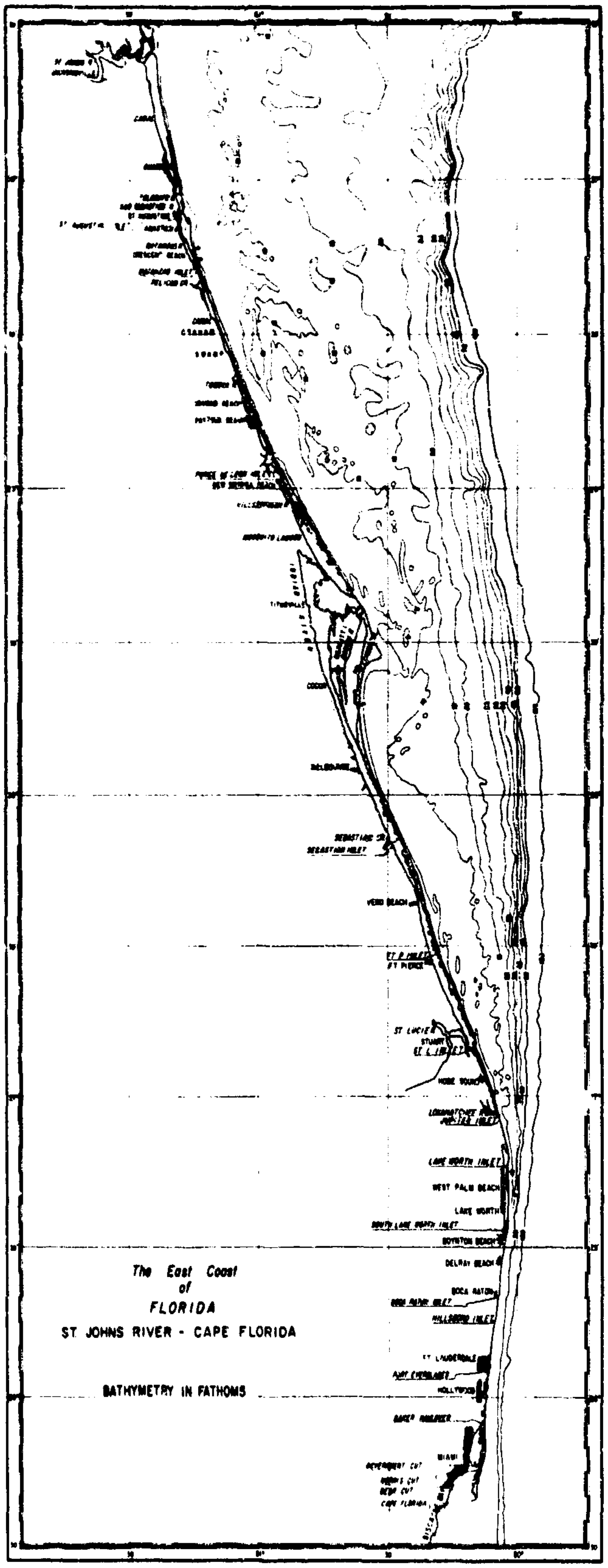

Figure 2. Concave shoreline with broad shelf occurs north of Cape Kennedy and convex shoreline with rapidly narrowing shelf extends to the south of the Cape. The Lake Worth to Miami area appears to be structurally positive, perhaps related to the Ocala Arch, whereas the areas to the north and south appear to be subsiding.

The answers to the above questions cannot be answered entirely except by a very complete investigation of the littoral environment; including the source and composition of the littoral materials, the forces acting on them, and their transport along shore and possibly into deeper water. All of these facets of the problem could not be studied within the limitations placed on the present investigation, but information pertinent to the problem has already been generated in other areas.

Inman and Rusnak (1956), for example, have demonstrated accurately and significantly that some of the sand movement involved in beach transport occurs out to water depths greater than about 50 feet. However, most of the active sand movement occurs within the narrow shore zone lying between the berm and a depth of about 30 feet. Within this zone, on the southern California coast, where waves are normally higher and the shelf is narrower than the Florida coasts experience, (see figure 2 for Florida East Coast shelf width) seasonal changes in sand level are relatively great. During winter, short period storm waves drift sand offshore and during summer long period swell and waves drift sand shoreward. Variations of sand thickness exceed two feet at water depths shoaler than 18 feet and are less than about 0.3 feet at water depths greater than 30 feet. This observation is important in any consideration of shell nourishment of beaches because it indicates <u>the sediment-reworking-depth</u> (i.e., sets limits for uncovering buried shell) from which available shells may be removed and transported shoreward. As most contemporaneous beach shell materials however consist of bottom-sediment burrowing mollusk assemblages which live largely in the active shore-zone (see for example figure 3), where high sand transport and detrital movement prevails (Hedgpeth, 1957), it is obvious that these forms are, quantitatively, the most important in nourishing beaches. Some burrowing mollusks occur at water depths exceeding 30 feet also but, because the general thickness of sand reworking (Inman and Rusnak, 1956) is slight here, there is less opportunity for reworking the buried shell shoreward by wave action and drift.

Recent marine geological studies have conclusively shown that many areas of the continental shelves are regions of non-accumulation, exhibiting relict sediments deposited on them during periods of glacially lowered sea level (Rusnak, 1962, and in manuscript). The continental shelf of Florida (figure 4) displays many such areas of non-deposition and relict sediments (Gould and Stewart, 1955; Pilkey, 1963; Gorsline, 1963). These areas are especially evident at water depths greater than about 50 to 60 feet, where very little sediment seems to be carried or seems to be in motion (Inman and Rusnak, 1956). The medium-grained (figure 5) relict deposits found there are typified by worn, stained and corroded shell fragments and oxidized sediments only slightly admixed with contemporaneous sediments or they may even be devoid of significant recent sediment contributions Emery, 1952). This may be taken as supporting evidence that alongshore transport is restricted to the shoals and does not extend far out onto the shelf. We therefore might tentatively consider that most of the offshore shell additions to the Florida East Coast beaches probably originate from depths no greater than 30 to 40 feet of water.

With this mechanical model and general setting in mind, the sources of shell within the narrow zone of active sand transport can now be considered: (1) the shell may be "new shell" supplied continuously by an active contemporaneous shell population; or, (2) it may represent "old shell" eroding from local relict deposits or shoreline and shoalwater geological outcrops (before, during and after barrier growth). The first source (1) indicates continuous nourishment while the second source (2) demonstrates local (or possibly more distant) erosion of old materials in the nearshore zone. Other factors being equal, the relative proportion of new and old shell in the beach sediment may then be thought of as an "Erosion Index" which could indicate whether erosion or build-up of a beach were in progress.* For the present problem, however, it is more important to know how much, if any, of the beach materials between Lake Worth Inlet and the Miami Ship Channel consists of new shell so that an accurate assay of controlled nourishment procedures could be made. To do this it must be possible to distinguish between new and old shell quantitatively.

The question of recognizing and distinguishing new from old shell must also be considered to trace possible routes of sand loss out over narrow reaches of the continental shelf to deep water. This point is extremely critical in fulfilling the future identification of mechanisms of sediment loss by attrition or deep-water capture.

In order to assess the importance of new and old shell contributions to the littoral drift material along the beach and nearshore, it is necessary to (1) establish criteria for the recognition of new and old shell either by direct microscopic or macroscopic observational techniques or else (2) to develop independent methods of estimating the relative contribution from each source to the sediment. Under the first approach (1) one might consider (a) standard paleontological criteria based on species differences which could be attributed to age or (b) secondary features such as staining and corrosion due to weathering age. The second approach (2) might consider (a) variations in sample mineralogy attributable to alteration phenomena reflecting age or (b) measured variations in the relative activity of the natural radiocarbon associated with admixtures of new and old shell carbonate.

It is unlikely that a simple set of standard paleontologic criteria could suffice for the recognition and distinction of new and old shell here. The major source of shell from local coquina rock

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* Use of the ratio of living to dead Foraminifera populations has been used (Phleger, 1956; Rusnak, 1960) to estimate sedimentation rates (an accumulation index) which would be the converse of the above.

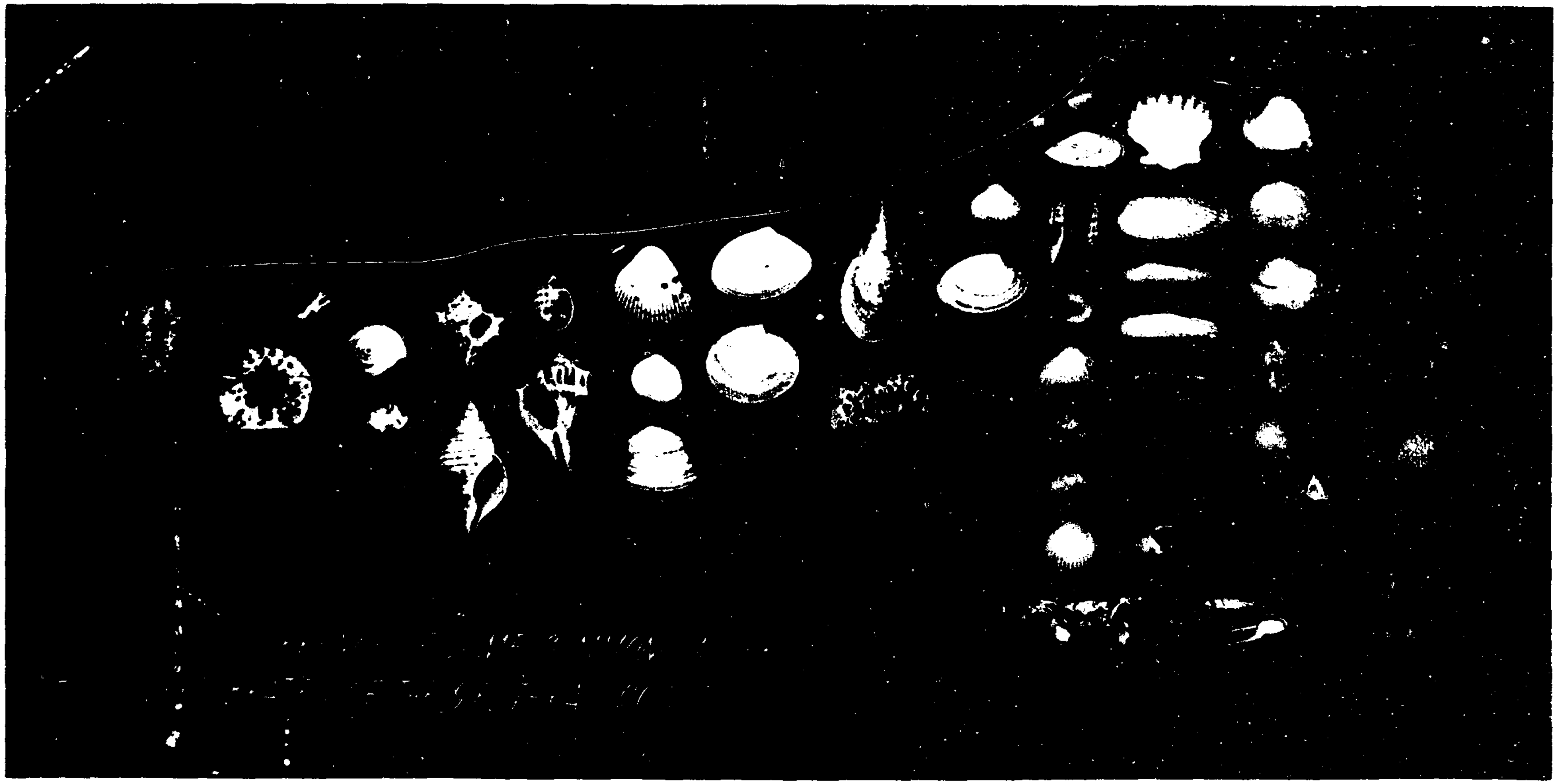

Figure 3. Generalized occurrence of some common megainvertebrates in the coastal environments of Southeast Texas. (After Bernard, 1962). These varieties are very similar to qualitative observations of species found along the Florida coast.

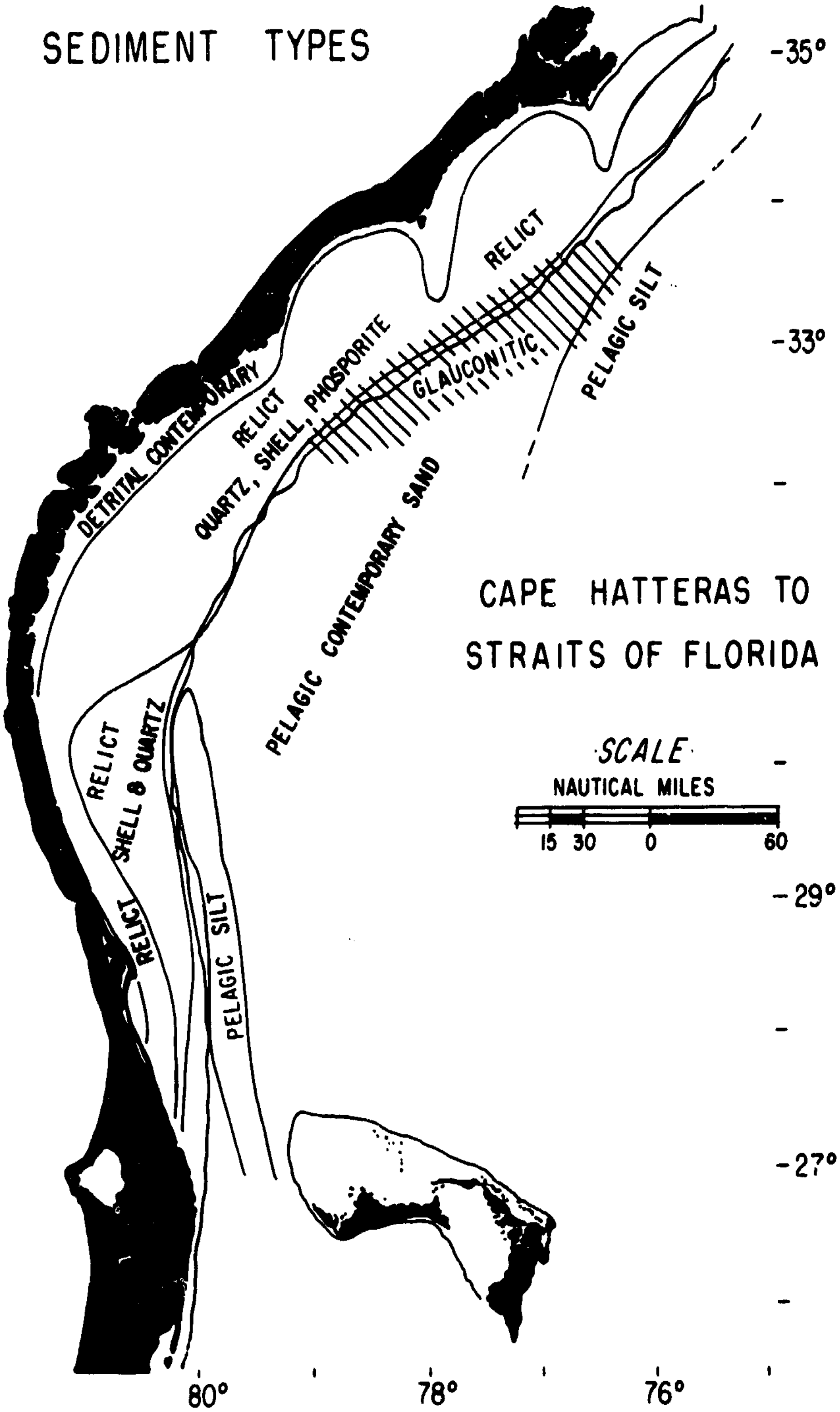

Figure 4. Sediment types. (Adapted from Gorsline, 1963.)

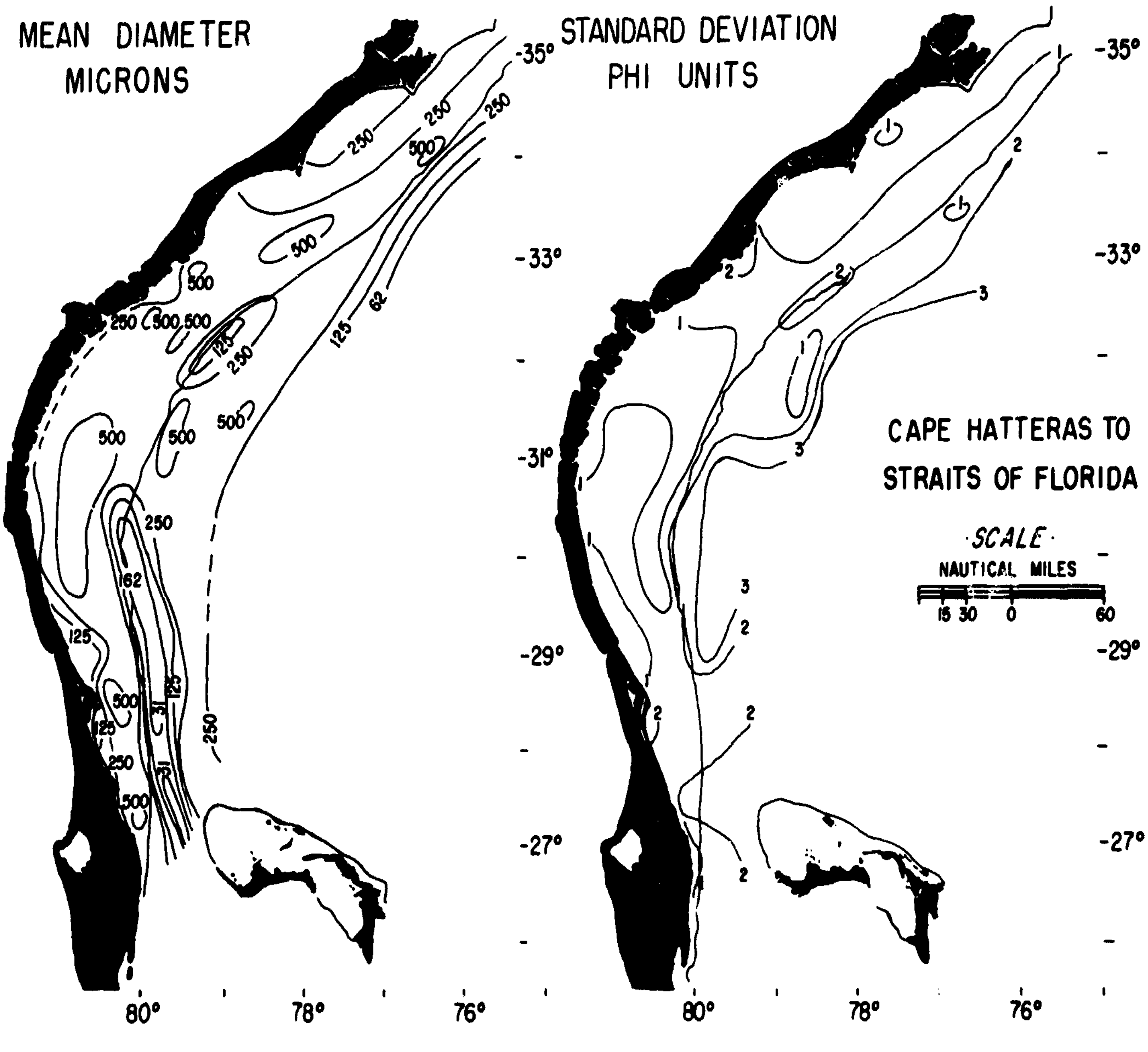

Figure 5. Textural parameters of terrace sediments. (Adapted from Gorsline, 1963.)

appears to be the Anastasia Formation which outcrops along the shoreline for a very considerable distance north of the study area. However, the Anastasia is a Late Pleistocene coquina rock which does not differ significantly in species abundance or species variety from living forms now occurring along the same shoreline. Therefore, criteria other than paleontologic are required.

The secondary features of staining and corrosion, which result from weathering and have often been applied to the recognition of aged shells (see for examples, Pilkey, 1963; Gorsline, 1963), offer only very qualitative estimates of the relative contribution of new and old shell to the area. Many samples from outcrops of the Anastasia, for example, appear to be as fresh as samples of shell obtained from living organisms on the beach. And many of the old shells which do show some staining also indicate polished surfaces which were obviously created through natural attrition and grinding after finding their way to the shoreline. Thus, corrosion and staining can indicate presence of old shell, under the assumption that these features are correlative, but that criteria alone is inadequate for quantitative evaluation.

Although neither paleontology nor weathering effects provide criteria for quantitative evaluation of old and new shell contribution to beaches, mineralogical variations might provide such distinguishing criteria if it could be established that the Pleistocene Anastasia Formation shell debris differed mineralogically from recent shell. Theoretically, quantitative results could be made by x-ray diffraction analysis of the whole sample mineralogy.

Our studies of the Anastasia coquina shows that the highly friable (i.e., relatively uncemented) rock consists of approximately equal amounts of calcite and aragonite. Because the shell here is dominated by <u>Donax</u> (the common coquina), which is aragonitic entirely, we could conclude that the shell has been altered through the inversion of aragonite (the orthorhombic variety of $CaCO_3$) to calcite (the hexagonal form of $CaCO_3$). Some calcite is undoubtedly introduced as a cementing agent but the relatively loosely consolidated nature of the samples examined suggests this to be secondary in importance. Calcite very likely forms a higher percentage of the more firmly cemented rocks as found elsewhere (Rusnak, 1960; Russell, 1962). Both calcite cementation and aragonite inversion to calcite proceed more quickly under environmental conditions whereby carbonate-saturated meteoric waters (rain) percolate around shell. Thus, the Anastasia apparently exhibits its past history of exposure to atmospheric weathering during glacially lowered sea level.

<u>Donax</u>, <u>Cadokia</u> and <u>Chione</u> commonly form shell deposits from presently living populations. These forms among many others are common shoreline species in the Florida area (compare with figure 3) and consist entirely of aragonite shells. Therefore, one could conclude that carefully controlled sample analyses of the beach samples under study would provide a good index of the relative contributions of aragonite and calcite to the beach material. There is a danger, however, of serious

error in reaching conclusions about the relative contribution of new and old shell because many living forms among the beach representatives also secrete calcite in their shell structure (see for example, Lowenstam, 1954; and, Pobeguin, 1954). Indeed, mineralogical analyses performed on carbonate deposits from the shelf areas on the Florida east coast cast serious doubts upon the validity of applying this mineralogical criteria to evaluate the relative age of shell debris (Pilkey, personal communication). We have therefore chosen to ignore this method of approach until more intensive sample study were available for a critical application to the beach problem

The one quantitative method that seemingly provides the best evaluation of "age" of shells contributed to the beach falls to technique of radiocarbon analysis. Clearly, the dilution of the value of modern carbonate radiocarbon activity is a function of the relative amounts of old or radioactively "dead" carbon added to the sample, assuming only that little, if any, other chemical exchange has occurred. This measure may thereby provide a unique method of establishing the relative proportion of recent and old shell present in the total carbonate fraction, of course, within certain limiting assumptions (Broecker and Kulp, 1956; Olson and Broecker, 1958).

METHODS OF STUDY

Samples for the study were collected systematically from dunes and along the shoreline of the Florida East Coast (figure 6; table I). Shoreline samples were first collected from approximately the top 1 cm of an area 1 meter square at about the mid-tide line on the beach. However, some modification of the ideal had to be made because it was obvious that very often exposed thin layers of shell would bias the results badly as they represented placers. The initial sampling technique was therefore changed to quartered samples collected from approximately 20 cm cubes cut down into the beach. Dune samples were collected with a post hole digger down to the ground water table in order to evaluate any vertical change. Samples from the Florida Straits (figure 7) were collected with a gravity corer or orange peel grab.

Collected samples were examined megascopically and with a 20X hand lense to obtain a qualitative impression of their makeup and uniformity. In the laboratory quantitative analyses were conducted on texture by sieving washed samples in glass-bead calibrated sieves (Herdan, 1960; and Appendix C). In addition, the acid digestion of carbonate shell materials provide a quantitative analysis of the total shell content by observed weight loss.

Beach materials were also subjected to abrasion mill (plate 2; and Appendix D) studies to evaluate the loss of shell material from the beach by abrasion. The abrasion mill studies attempted to duplicate the natural abrasive conditions by the use of naturally occuring beach sand with a substantial quantity of shell fragments admixed with quartzose particles. Some fragments of Anastasia outcrop coquina were

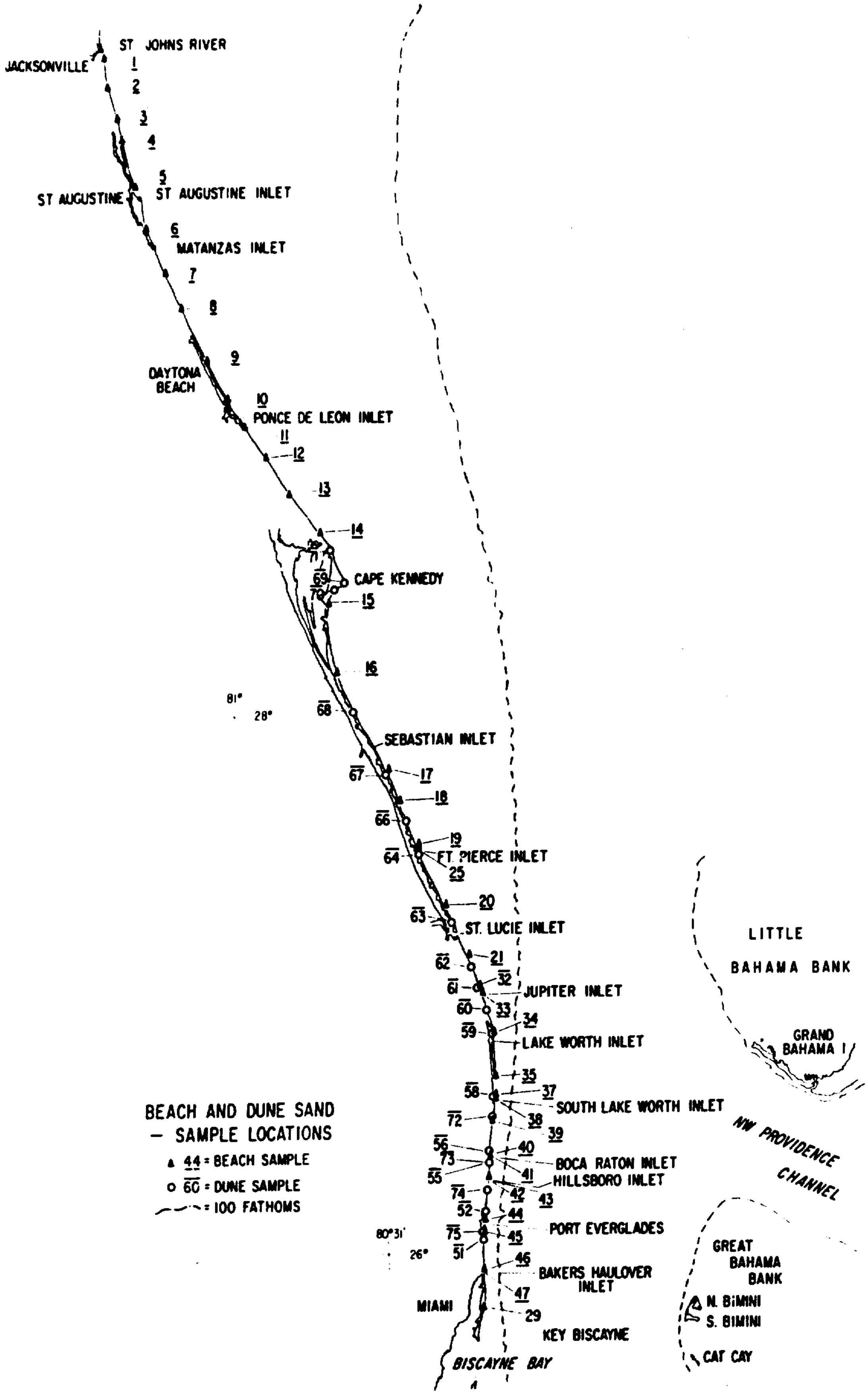

Figure 6. Beach and Dune sand sample locations.

TABLE I

Latitude[1]	Station	Miles[2] Between Stations: Beach	Dune	C_{14}	Rock	Cumulative Miles[2] From Origin: Beach	Dune	C_{14}	Rock	Sample Types: Beach	Dune	C_{14}	Rock
25°46.0'	29	0				0				X			
25°53.9'	47	7.9				7.9				X			
25°54.1'	46	0.2				8.1				X			
26°02.0'	51		0				16.0				X		
26°03.1'	75		1.1				17.1				X		
26°03.2'	45	9.1				17.2				X			
26°05.7'	44	2.5				19.7				X			
26°08.6'	52		5.5				22.6				X		
26°13.7'	74		5.1				27.7				X		
26°15.4'	43	9.7				29.4				X			
26°15.5'	42	0.1				29.5				X			
26°16.6'	54			0				30.6				X	
26°19.5'	55		5.8				33.5				X		
26°20.1'	41	4.6				34.1				X			
26°20.3'	40	0.2				34.3				X			
26°20.6'	73		1.1				34.6				X		
26°22.9'	56		2.3				36.9				X		
26°27.5'	39	7.2				41.5				X			
26°28.6'	72		5.7				42.6				X		
26°32.7'	38	5.2				46.7				X			
26°32.7'	37	0				0				X			
26°32.8'	57			17.2				46.8				X	
26°34.0'	58		5.4				48.0				X		
26°37.0'	35	4.3				51.0				X			
26°47.2'	34	10.2				61.2				X			
26°47.6'	59		13.6				61.6				X		
26°53.1'	60		5.5				67.1				X		
26°56.3'	33	9.1				70.3				X			
26°57.8'	32 & 49	1.5		0		71.8		71.8		X #32			X #32 #49
26°58.3'	61		5.2				72.3				X		
26°58.6	22 & 36				0.8								X
27°02.6'	62		4.3				76.6				X		
27°03.9'	21	6.1				77.9				X			
27°12.6'	63		10.0				86.6				X		
27°15.3'	20	11.4				89.3				X			
27°27.5'	64		14.9				101.5				X		
27°28.1'	25	12.8				102.1				X			
27°28.5'	19	0.4				102.5				X			
27°29.4'	65			56.6				103.4				X	
27°35.0'	66		8.0				109.5				X		
27°39.0'	18	10.5				113.0				X			
27°45.8'	67		10.3				119.8				X		
27°45.8'	17	6.8				119.8				X			
27°59.8'	68		14.0				133.8				X		
28°08.3'	16	22.5				142.3				X			
28°23.6'	15	15.3				157.6				X			
28°26.3'	70		26.5				160.3				X		
28°27.8'	69		1.5				161.8				X		
28°35.0'	71		7.2	65.6			169.0	169.0			X	X	
28°38.6'	14	15.0				172.6				X			
28°47.5'	13	8.9				181.5				X			
28°55.4'	12	7.9				189.4				X			
29°02.6'	11	7.2				196.6				X			
29°08.7'	10	6.1				202.7				X			
29°17.5'	9	8.8				211.5				X			
29°28.7'	8	11.2				222.7				X			
29°36.3'	7	7.6			157.7	230.3			230.3	X			
29°46.2'	6	9.9				240.2				X			
29°55.0'	5	8.8				249.0				X			
30°04.9'	4	9.9				258.9				X			
30°09.7'	3	4.8				263.7				X			
30°16.1'	2	6.4				270.1				X			
30°23.1'	1	7.0				277.1				X			

25°43.9' - Beach sample for abrasion tests (B50)

[1]Intersection of latitudes with shoreline determines station locations.

[2]Miles are not shoreline distance but correspond to a meridian of longitude along w[illegible] of latitude = 60 miles. Cumulative miles shown for beach type samples represent the entire len[illegible] area.

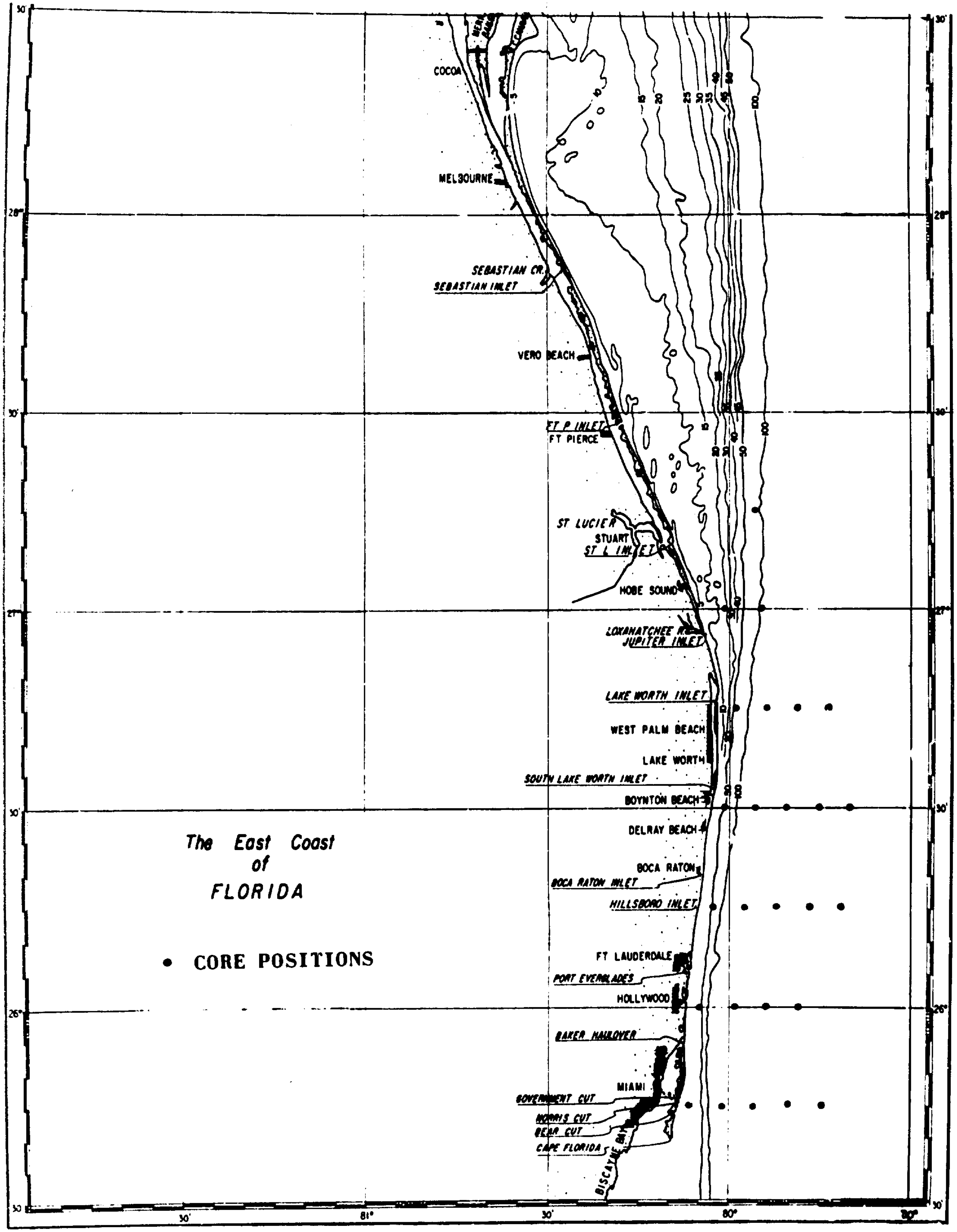

Figure 7. Core positions.

similarly subjected to abrasion to evaluate the effects of this mode of attrition on the partially consolidated coquina rock (Appendix D).

X-ray analysis were conducted on splits of mortar ground samples using accepted x-ray techniques in diffractometer analysis. Relatively high accuracy methodology (Supko, A63) was available but was found unnecessary when preliminary results indicated mineralogical distinction between Recent and older carbonate fragments was inconclusive. As a result of the lack of mineralogical distinction, only a set of samples judged to be representative was examined. Similar results could have been expected with microscopic examination and staining techniques and these methods were similarly abandoned as not quantitatively useful in evaluating relative contributions of old and new shell materials to the beach.

Radiocarbon assay of the carbonate fraction promised the greatest success in distinguishing between the relative contribution of old and new shell. The methods used for these analyses have been described numerous times before by others (see for example deVries, 1959). We used CO_2 as the counting gas in the 1 liter 3 atmosphere counter of the Radiocarbon Dating Laboratory of the Institute of Marine Science, University of Miami (Ostlund, Bowman, and Rusnak, 1962). Samples collected for radiocarbon analyses were collected from beach locations pertinent to the study (figure 8) as well as from the Anastasia formation.

DISCUSSION

Limited southerly transport of quartzose Piedmont sands apparently persisted throughout the Late Pleistocene as extensive quartzose deposits are found only in the northern two-thirds of the state of Florida. Moreover, the present geographic extent of quartzose-sand transport alongshore seems not to be greatly different (on a relative scale) from that in the past (Parker, et al, 1955).

Wave observations indicate a definite shift in wave direction at the 30° parallel with northeasterly generated waves below 30°N and southwesterly generated waves north of the 30°N parallel during the winter months. In the summer months the surface winds generate waves moving to the northwest above and below the 30°N parallel (U.S. Navy Hydro. Office, 1959, 1960). Thus, the steep northeasterly short-period waves which move sand offshore tend to encourage sand loss to deep water during the winter months at the narrow segments of the shelf. Less steep summer waves which move sand onshore approach mostly from the S.E. quarter. The effectiveness of the Bahama Banks as a barrier causing a wave shadow must certainly be felt as a strong net offshore movement of sand because little of the low-steepness-wave energy impinges on the area south of Palm Beach to move sand onshore (Watts, 1962).

Grain Size Analysis

All grain size analyses made were processed by the Institute of

Marine Science 1620 computer to calculate statistical parameters. The data-entry values compiled from ½ ∅ sieve intervals were programmed to provide Trask's quartile measures, Inman's (1952) percentiles, and Folk and Ward's (1957) expansion of percentile estimates for the estimated statistical parameters of mean, median, skewness, and kurtosis. These data form the second volume of this report as provided directly from the IBM printout.

The statistical values obtained for beach samples are summarized in Table II along with modal sizes as determined from (1) the total sand sample, (2) the insoluble residue left after acid digestion of the carbonate fraction, and (3) the carbonate fraction as recalculated from the difference between (1) and (2).

Dune samples were analyzed similarly and the resulting statistical parameters are listed in Table III. The statistical variation within each dune core-sample, for various depths within the sample, appears to be as great as between samples. However, this last statement requires a statistical test of variability which time did not permit for this report. The degree to which each of the parameters is influenced by the acid soluble (carbonate) fraction is clearly seen in the values obtained for the <u>core total</u> (CT), <u>core insolubles</u> (CI), and the <u>core carbonate</u> (CC) fraction, at each level of depth (in feet) analyzed in the core.

Both Tables II and III demonstrate that the larger size fraction is invariably the acid soluble constituent. Similarly, the overall grain-size of samples from north to south increases because of the increasing shell carbonate-content (figures 9 & 10); an observation which was readily apparent during megascopic inspection of samples during their collection. These data are in accord with those illustrated in figures 4 and 5.

Megascopic examination only was made of samples collected from the Florida Straits, but these indicate that the surficial shelf, slope and floor sediments of the Florida Straits consists almost entirely of carbonate sand varying in size grades from coarse in the shoals to fine and very fine sand and coarse silt on the floor (Table IV).

Bottom photography in the vicinity of Miami (Hurley, 1961) and sub-bottom seismic profiling data (Hurley, personal communication; Uchupi, 1966) indicate that large areas of the Florida Straits are covered with an apparently thick blanket of sand. Similarly, the geophysical survey conducted for the U.S. Army Corps of Engineers indicates that sand thicknesses of 30 feet or more occur between buried late Pleistocene ridges on the Florida East Coast Shelf (Norman Tanney, personal communication). Certainly some of the sand being lost from the shelf area between Lake Worth Inlet and Miami must be lost to the Florida Straits. Unfortunately, it is not possible to evalute the magnitude of this loss directly at present, but the observed rate of loss

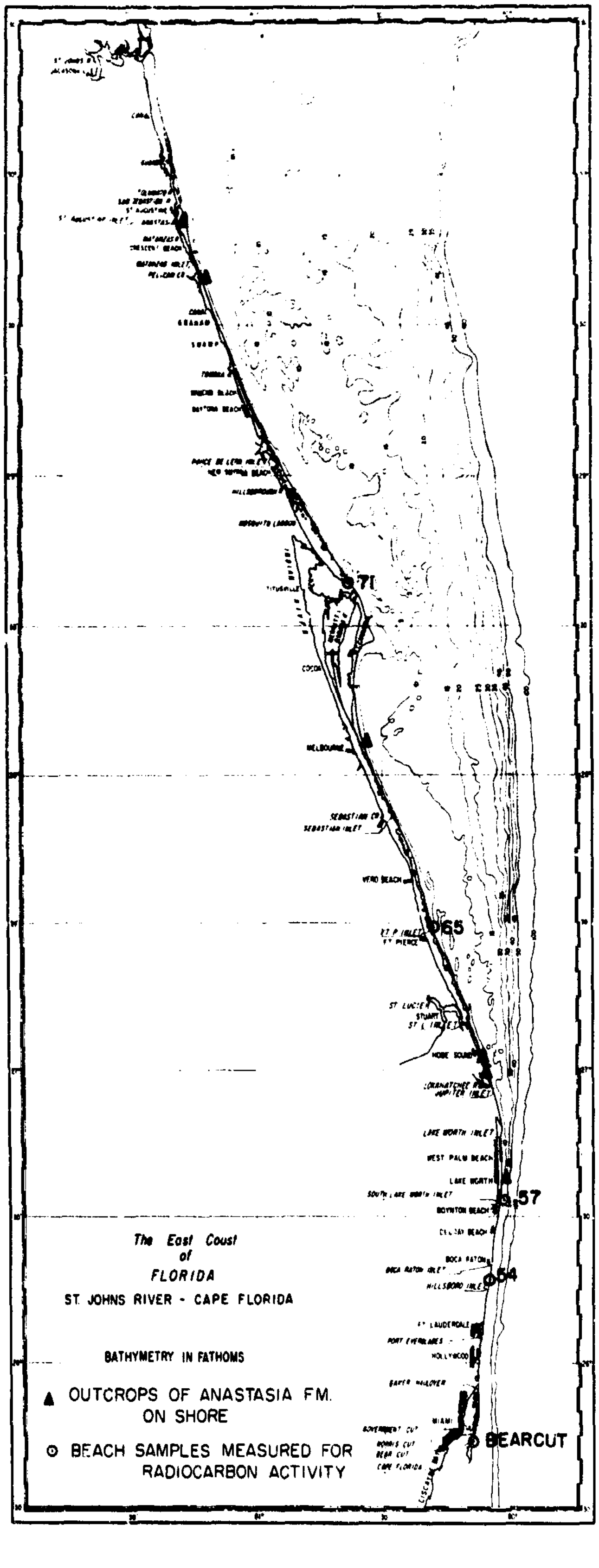

Figure 8. Location of beach samples collected for radiocarbon analyses. Known outcrops of Anastasia fm. coquina rock are also shown to demonstrate its relatively widespread occurrence.

BEACH SANDS

Φ VALUES (FOLK AND WARD)

Sample No.	No. classes Insol	No. classes Carb	Mean Total	Mean Insol	Mean Carb	Deviation Total	Deviation Insol	Deviation Carb	Skewness Total	Skewness Insol	Skewness Carb	Kurtosis Total	Kurtosis Insol	Kurtosis Carb	Principal Mode[1] Total	Principal Mode[1] Insol	Principal Mode[1] Carb		% Pre-mode	% Mode	% Post-Mode
24	8	10	2.24	[illegible]	2.22	0.49	0.47	0.49	-0.11	-0.25	-0.07	0.90	0.90	0.95	2.50	3.00	2.50	T	28.7	34.1	37.2
																		I	48.7	43.4	7.9
																		C	34.7	35.8	29.5
47	9	16	[illegible]	1.50	[illegible]	1.22	0.69	1.08	0.17	-0.25	0.30	0.76	1.12	1.05	-0.50*	2.00	-0.50*	T	13.0	17.6	69.4
																		I	43.5	35.4	21.1
																		C	17.4	23.5	59.3
46	9	12	0.72	1.04	0.58	0.61	0.42	0.63	-0.18	-0.04	-0.15	1.06	0.98	1.01	1.00	1.50	1.00	T	32.4	33.8	33.8
																		I	45.6	40.0	14.4
																		C	41.2	33.3	25.5
45	8	15	-0.30	1.17	-0.53	1.31	0.77	1.16	-0.02	0.05	-0.04	1.16	0.82	1.17	0 *	1.00*	-0.50*	T	44.0	16.2	39.9
																		I	20.9	24.2	54.9
																		C	32.7	18.6	48.7
44	9	14	0.37	1.44	0.01	1.22	0.87	1.05	0.18	-0.04	0.18	1.00	0.75	1.23	0 *	1.00*	0*	T	25.0	18.7	56.3
																		I	16.1	20.2	63.7
																		C	31.0	22.7	45.4
43	8	14	-0.19	0.96	-0.51	1.30	0.54	1.25	-0.32	0.07	-0.27	1.07	1.23	0.99	1.00*	1.00	0.50*	T	66.0	18.9	15.1
																		I	17.8	36.1	46.1
																		C	61.1	17.9	21.0
42	6	13	-0.10	0.99	-0.32	1.14	0.41	1.14	-0.21	-0.24	-0.16	1.04	1.07	1.15	1.00*	1.50	-0.50*	T	66.1	19.4	14.5
																		I	55.4	40.9	3.7
																		C	23.5	18.5	58.0
41	7	14	-0.52	0.53	-0.68	1.17	0.35	1.15	-0.32	-0.09	-0.32	1.20	1.40	1.23	0 *	1.00	0 *	T	45.2	20.1	34.7
																		I	37.5	52.9	9.6
																		C	50.7	21.7	27.6
40	8	14	-0.52	0.75	-0.83	1.32	0.42	1.36	-0.34	0.04	-0.30	0.85	1.23	0.85	1.00*	1.00	0.50*	T	74.0	19.4	6.6
																		I	24.4	50.5	25.1
																		C	50.1	14.7	35.2
39	8	14	-0.82	1.06	-1.15	1.68	0.47	1.59	-0.10	-0.09	0.06	0.73	1.05	0.74	1.00*	1.50	-1.50*	T	42.0	40.4	17.6
																		I	42.0	40.4	17.6
																		C	29.1	13.8	57.1
38	9	15	[illegible]	1.29	0.52	0.91	0.41	1.17	-0.44	-0.16	-0.45	1.44	1.00	1.35	1.50*	1.50	1.50*	T	46.7	31.7	21.6
																		I	23.6	42.8	33.6
																		C	62.4	24.1	13.5
37	8	13	0.89	1.41	0.62	0.90	0.47	1.06	-0.35	-0.13	-0.29	1.23	0.98	1.07	1.50*	2.00	1.00*	T	44.5	25.6	29.9
																		I	53.9	37.7	8.4
																		C	39.0	21.9	39.1
35	7	11	1.41	1.54	1.25	0.53	0.42	0.61	-0.12	-0.08	-0.03	0.97	0.99	0.94	2.00*	2.00	1.50*	T	53.4	34.8	11.8
																		I	43.3	43.3	13.4
																		C	35.8	28.8	35.4
34	8	11	1.41	1.58	1.21	0.56	0.41	0.67	-0.28	-0.19	-0.19	1.04	1.07	1.01	2.00	2.00	2.00	T	49.7	40.0	10.3
																		I	36.8	50.8	12.4
																		C	62.8	29.1	8.1
33	8	9	1.49	1.61	1.33	0.49	0.40	0.56	-0.16	-0.09	-0.11	1.02	1.02	0.97	2.00	2.00	2.00	T	46.5	40.1	13.4
																		I	36.9	46.9	16.2
																		C	59.0	31.1	9.9
32	8	10	1.28	1.37	1.15	0.41	0.35	0.45	-0.10	-0.07	-0.06	0.99	1.01	0.96	1.50	1.50	1.50	T	24.8	43.3	31.9
																		I	15.4	46.1	38.5
																		C	36.7	39.7	23.6
21	9	13	0.61	1.25	0.36	0.96	0.71	0.90	-0.25	0.57	0.35	1.62	1.92	1.13	1.00*	1.50*	1.00*	T	35.2	28.1	36.7
																		I	34.0	41.9	24.1
																		C	48.1	28.0	33.9
20	10	14	2.08	2.46	1.52	1.04	0.84	1.07	-0.22	-0.43	0.09	0.74	0.77	0.80	3.00*	3.50*	1.00*	T	56.8	21.0	22.2
																		I	67.3	30.4	2.3
																		C	18.1	18.3	63.6
25	11	13	1.09	1.66	0.43	1.20	0.99	1.06	0.13	0.17	0.22	0.97	0.86	1.24	1.00*	1.50*	0.50	T	33.7	17.2	49.1
																		I	28.4	20.7	50.9
																		C	38.3	22.0	39.7
19	9	17	2.83	3.01	2.04	0.72	0.50	1.23	-0.46	-0.27	-0.47	1.60	1.50	0.96	3.50*	3.50	3.00*	T	52.1	39.3	8.6
																		I	44.6	45.3	10.1
																		C	53.0	26.4	20.6
18	9	9	2.34	2.39	2.04	0.60	0.56	0.82	-0.10	-0.02	-0.33	1.09	1.01	1.14	2.50	2.50	2.50	T	27.4	32.8	39.3
																		I	24.0	34.0	42.0
																		C	40.1	28.5	31.4
17	8	8	1.88	1.93	1.69	0.51	0.48	0.63	-0.04	0.03	-0.21	1.12	1.10	1.08	2.00	2.00	2.00	T	21.3	37.9	40.3
																		I	17.3	39.1	43.6
																		C	33.7	33.8	32.5
16	8	8	1.72	1.75	1.52	0.49	0.46	0.62	-0.04	-0.02	-0.07	1.01	0.99	1.01	2.00	2.00	2.00	T	32.0	39.3	28.7
																		I	28.9	41.0	30.1
																		C	47.4	31.0	21.6
15	9	14	1.43	1.59	0.98	0.78	0.69	0.86	-0.11	-0.07	-0.04	0.98	0.98	0.93	2.00	2.00	1.00*	T	51.0	25.3	23.7
																		I	42.8	28.6	8.7
																		C	28.3	21.8	49.9
14	8	10	1.34	1.44	0.98	0.62	0.57	0.65	-0.01	0.04	0.02	1.07	1.09	0.97	1.50	1.50	1.00	T	28.6	31.2	40.2
																		I	21.4	32.7	45.9
																		C	23.4	28.2	48.4
13	10	12	2.09	2.59	0.57	1.05	0.52	1.24	-0.70	-0.51	0.18	1.29	1.90	1.04	3.00*	3.00*	0	T	45.9	47.7	6.4
																		I	34.1	58.2	7.7
																		C	17.3	19.1	63.6
12	10	14	1.67	2.59	-0.04	1.40	0.61	0.92	-0.57	-0.53	0.16	0.62	2.41	1.23	3.00*	3.00*	0	T	56.6	35.3	8.1
																		I	34.8	53.2	12.0
																		C	29.1	26.5	44.4
11	9	14	2.75	2.76	1.29	0.35	0.31	1.42	-0.28	-0.18	-0.30	1.24	1.12	0.80	3.00*	3.00	2.00* & 2.50	T	22.4	57.8	19.8
																		I	19.2	60.2	20.6
																		C	47.8	31.2	21.0
10	9	15	2.58	2.62	1.53	0.48	0.41	0.92	-0.36	-0.30	-0.02	1.15	1.09	1.17	3.00*	3.00	1.50*	T	35.7	47.9	14.4
																		I	32.1	52.6	15.3
																		C	26.5	23.6	49.9
9	8	8	2.32	2.37	1.61	0.46	0.39	0.66	-0.25	-0.20	0.10	1.08	1.04	0.97	2.50	2.50	2.00	T	23.1	37.7	39.2
																		I	18.2	39.8	42.0
																		C	45.3	28.3	26.4
8	8	10	1.40	1.90	0.56	0.91	0.52	0.74	-0.25	-0.09	0.03	0.89	0.95	1.00	2.00	2.00	1.00	T	48.0	23.5	28.5
																		I	23.4	32.7	43.9
																		C	46.8	27.0	26.2
7	9	11	0.56	1.68	-0.28	1.31	0.71	0.94	-0.01	-0.07	0.05	0.81	0.92	1.06	0 *	2.00	0	T	60.2	12.5	27.3
																		I	39.8	26.0	34.2
																		C	41.4	23.7	35.2
6	7	11	2.60	2.60	1.88	0.33	0.33	1.05	-0.19	-0.18	-0.17	1.06	1.06	0.95	3.00	3.00	2.50	T	34.0	57.3	8.7
																		I	33.4	58.0	8.6
																		C	33.4	53.7	12.9
5	9	15	1.76	1.94	0.37	0.82	0.62	1.22	-0.27	-0.16	-0.22	1.06	0.94	1.62	2.50*	2.50	0.50*	T	56.7	26.8	16.5
																		I	50.5	30.7	18.8
																		C	33.6	21.0	45.4
4	12	16	1.00	1.85	-0.51	1.49	0.76	1.13	-0.31	-0.29	-0.05	0.82	0.88	1.13	2.50*	2.50*	-0.50*	T	68.2	18.4	13.4
																		I	50.2	28.7	21.1
																		C	32.0	19.0	49.0
3	11	15	0.09	1.39	-0.63	1.36	1.04	0.87	0.34	-0.30	-0.06	1.01	0.81	1.58	0 *	2.50	-0.50*	T	20.6	21.3	58.1
																		I	65.5	22.7	11.8
																		C	30.1	29.6	40.3
2	10	17	2.60	2.64	-0.90	0.70	0.38	1.99	-0.47	-0.20	0.14	2.55	1.13	1.40	3.00*	3.00*	-1.00*	T	35.0	50.7	14.3
																		I	30.8	54.1	15.1
																		C	36.2	14.8	49.0
1	10	17	2.75	2.78	1.60	0.46	0.41	1.33	-0.26	-0.18	-0.23	1.17	1.11	2.20	3.00*	3.00	2.00*	T	25.4	45.2	29.4
																		I	22.5	47.1	30.4
																		C	42.0	27.2	30.8
RANGES																					
	6	9	3.35	2.48	3.12	1.16	0.73	1.54	1.04	1.10	0.82	1.93	1.66	1.40	3.50	2.00	4.00	T	61.0	45.3	63.0
																		I	51.9	40.0	61.4
																		C	45.5	39.9	55.5

1. Principal mode recorded for those samples with asterisk. Other samples are unimodal.

* Polymodal samples. Twenty-six of the modes have peaks whose values are less than one per cent greater than the highest of the low values on either side.

TABLE III

Coastal Dune Cores
Ø Values (Folk & Ward)

Sample No.	Depth in feet	Mean	Dev	SK	Kurt	Principal Mode *=Polymodal	% pre-mode	% Mode	% Post mode
51-CT-	2.0	1.18	0.70	-0.22	0.95	2.00	62	29	9
	4.3	1.10	0.74	-0.14	0.93	2.00	66	25	9
51-CI-	2.0	1.48	0.48	-0.23	0.92	2.00	46	41	13
	4.3	1.43	0.53	-0.18	0.87	2.00	50	36	14
51-CC-	2.0	0.93	0.77	-0.11	0.91	1.50	52	23	25
	4.3	0.85	0.79	-0.04	0.93	1.00	32	25	43
75-CT-	1.0	1.47	0.84	-0.44	1.31	2.00	41	35	24
	3.0	0.68	0.68	-0.06	0.96	1.00	30	29	33
	6.0	1.02	0.91	-0.26	0.87	2.00	63	27	10
	7.0	0.71	1.00	-0.16	0.88	1.00*	39	20	41
	8.0	0.47	0.94	+0.15	0.99	0.50*	34	22	44
75-CI-	1.0	1.79	0.48	-0.20	1.19	2.00	24	43	33
	3.0	1.10	0.50	-0.01	0.92	1.50	44	33	23
	6.0	1.51	0.54	-0.28	0.95	2.00	42	41	17
	7.0	1.37	0.58	-0.15	0.85	2.00	54	33	13
	8.0	1.22	0.71	-0.05	0.75	2.00*	59	27	14
75-CC-	1.0	1.09	1.07	-0.41	1.01	2.00	56	27	17
	3.0	0.50	0.66	-0.01	0.96	1.00	49	28	23
	6.0	0.71	0.97	-0.07	0.83	1.00*	42	18	40
	7.0	0.42	1.03	-0.07	0.97	1.00	52	20	28
	8.0	0.19	0.83	+0.13	1.12	0.50	43	25	32
52-CT-	2.0	1.42	0.63	-0.21	0.97	2.00	50	34	14
	5.0	1.28	0.61	-0.19	1.08	1.50	30	31	39
52-CI-	2.0	1.60	0.50	-0.16	1.02	2.00	37	42	21
	5.0	1.50	0.45	-0.12	1.02	2.00	47	41	12
52-CC-	2.0	1.24	0.69	-0.11	0.92	2.00	62	27	12
	5.0	1.12	0.67	-0.16	1.08	1.50	40	30	30
74-CT-	1.0	1.55	0.56	-0.13	1.03	2.00	42	38	20
	3.0	1.77	0.36	-0.14	1.09	2.00	22	52	26
	5.0	1.64	0.40	-0.21	1.08	2.00	33	50	17
	7.0	1.05	0.79	-0.31	0.97	2.00	66	27	7
	9.0	1.51	0.37	-0.13	1.01	2.00	45	47	8
	11.0	1.21	0.59	-0.11	1.04	1.50	35	32	33
74-CI-	1.0	1.67	0.48	-0.09	1.00	2.00	33	41	26
	3.0	1.81	0.33	-0.08	1.07	2.00	17	55	28
	5.0	1.73	0.34	-0.10	1.11	2.00	24	57	19
	7.0	1.49	0.45	-0.21	1.04	2.00	46	44	10
	9.0	1.59	0.32	-0.07	1.04	2.00	37	54	9
	11.0	1.45	0.44	-0.08	0.96	2.00	52	38	10
74-CC-	1.0	1.37	0.59	-0.09	1.02	2.00	55	32	13
	3.0	1.72	0.41	-0.15	1.08	2.00	27	49	24
	5.0	1.54	0.47	-0.22	1.03	2.00	42	44	14
	7.0	0.82	0.85	-0.20	0.91	1.50	54	23	23
	9.0	1.43	0.41	-0.12	0.97	2.00	54	39	7
	11.0	1.05	0.63	-0.07	1.07	1.50	47	29	24
55-CT-	2.5	1.31	0.48	-0.19	0.99	1.50	26	36	38
55-CI-	2.5	1.48	0.36	-0.18	1.00	2.00	48	47	5
55-CC-	2.5	1.19	0.52	-0.13	0.99	1.50	35	35	30
73-CT-	1.0	1.14	0.47	-0.09	0.92	1.50	39	36	25
	3.0	1.01	0.52	-0.06	1.00	1.00	16	33	51
	5.0	1.32	0.50	-0.23	1.03	2.00	60	36	4
	8.0	0.63	0.49	-0.11	1.18	1.00	36	44	20
	10.0	0.33	0.61	-0.19	1.08	1.00	57	33	10
	12.0	0.21	0.57	-0.03	1.04	0.50	35	34	31
	14.0	-0.20	0.58	-0.01	1.05	0	30	35	35
73-CI-	1.0	1.28	0.39	-0.10	0.90	1.50	26	42	32
	3.0	1.21	0.41	-0.03	0.91	1.50	33	41	26
	5.0	1.45	0.37	-0.18	0.92	2.00	49	46	5
	8.0	0.88	0.36	+0.10	1.09	1.00	13	53	34
	10.0	0.78	0.40	+0.10	1.16	1.00	23	52	25

TABLE III

Coastal Dune Cores
ϕ Values (Folk & Ward)

Sample No.	Depth in feet	Mean	Dev	SK	Kurt	Principal Mode *=Polymodal	% pre-mode	% Mode	% Post mode
73-CI-	12.0	0.68	0.48	+0.11	1.05	1.00	36	41	23
	14.0	0.46	0.54	+0.12	1.11	0.50	18	36	46
73-CC-	1.0	1.02	0.51	-0.02	0.94	1.00	15	33	52
	3.0	0.89	0.54	-0.04	1.01	1.00	22	36	42
	5.0	1.21	0.56	-0.17	1.03	1.50	35	32	33
	8.0	0.54	0.50	-0.13	1.15	1.00	43	41	16
	10.0	0.24	0.60	-0.18	1.04	0.50	32	31	37
	12.0	0.14	0.54	-0.04	1.02	0.50	39	35	26
	14.0	-0.24	0.56	0.00	1.06	0	32	36	32
56-CT-	3.0	0.60	0.52	-0.05	1.16	1.00	39	41	20
	6.5	1.13	0.61	-0.19	0.93	1.50	39	30	31
	9.8	0.42	0.91	-0.26	1.19	1.00	49	25	26
	11.7	0.13	1.05	-0.14	0.95	1.00*	60	18	22
	13.0	0.19	1.05	-0.20	1.09	1.00	59	19	22
56-CI-	3.0	0.92	0.41	+0.14	1.00	1.00	14	48	38
	6.5	1.41	0.42	-0.20	1.00	2.00	54	41	5
	9.8	0.99	0.71	-0.36	1.63	1.50	46	37	17
	11.7	1.04	0.69	-0.37	1.44	1.50	42	35	23
	13.0	1.00	0.71	-0.37	1.38	1.50	45	34	21
56-CC-	3.0	0.52	0.51	-0.08	1.14	1.00	46	39	15
	6.5	0.99	0.65	-0.09	0.90	1.50	49	27	24
	9.8	0.28	0.90	-0.24	1.22	1.00	56	25	19
	11.7	-0.03	1.02	-0.09	1.00	0	30	19	51
	13.0	0.03	1.04	-0.17	1.16	0.50	46	21	33
72-CT-	1.0	1.32	0.52	-0.10	0.93	1.50	28	32	40
	3.0	0.95	0.44	+0.01	1.08	1.00	14	42	44
	6.0	0.13	1.20	-0.38	0.89	1.00	51	24	25
	9.0	1.16	0.91	-0.47	2.01	1.50	33	32	35
	11.0	1.09	0.82	-0.21	0.92	2.00	64	26	10
	13.0	1.18	0.64	-0.14	0.91	2.00	65	28	7
72-CI-	1.0	1.45	0.44	-0.10	0.93	2.00	52	39	9
	3.0	1.11	0.36	+0.10	0.96	1.50	41	44	15
	6.0	1.09	0.46	+0.01	1.04	1.50	44	38	18
	9.0	1.43	0.40	-0.13	1.02	2.00	53	41	6
	11.0	1.47	0.53	-0.20	0.95	2.00	47	39	14
	13.0	1.41	0.48	-0.16	0.94	2.00	53	38	9
72-CC-	1.0	1.16	0.58	-0.02	0.96	1.50	41	30	29
	3.0	0.83	0.46	+0.01	1.13	1.00	22	45	33
	6.0	-0.20	1.19	-0.2[illegible]	0.80	1.00	65	20	15
	9.0	0.74	1.33	-0.54	1.85	1.50	48	27	25
	11.0	0.78	0.87	-0.03	0.85	1.00	38	21	41
	13.0	0.96	0.68	0.00	0.88	1.00	26	26	48
58-CT-	1.0	1.39	0.49	+0.14	1.09	1.50	21	40	39
	3.0	1.80	0.43	+0.01	1.14	2.00	23	46	31
58-CI-	1.0	1.38	0.48	+0.12	1.09	1.50	21	40	39
	2.5	1.58	0.55	-0.15	1.01	2.00	39	39	22
	3.0	1.79	0.42	0.00	1.12	2.00	23	47	30
58-CC-	1.0	1.99	1.13	+0.12	1.64	2.00	28	31	41
	2.5	1.36	1.40	-0.05	1.35	2.00	51	23	26
	3.0	1.25	1.58	-0.14	1.11	2.00	50	20	30
59-CT-	1.0	1.09	0.58	-0.09	1.06	1.50	43	33	24
	4.0	1.03	0.72	-0.12	1.07	1.50	46	27	27
	5.9	1.27	0.66	-0.13	1.27	1.50	31	31	38
59-CI-	1.0	1.30	0.44	-0.01	0.98	1.50	25	40	35
	4.0	1.35	0.51	+0.02	1.08	1.50	24	36	40
	5.9	1.44	0.49	-0.01	1.12	1.50	18	35	47
59-CC-	1.0	0.88	0.63	-0.06	1.07	1.00	25	32	43
	4.0	0.74	0.76	-0.04	0.99	1.00	36	28	36
	5.9	0.86	0.89	-0.06	1.24	1.00	30	26	44
60-CT-	0.7	1.54	0.56	-0.05	1.22	2.00	44	38	18
	2.2	1.56	0.43	-0.08	1.12	2.00	40	46	14
	7.0	1.43	0.50	-0.20	1.05	2.00	51	39	10
	10.0	1.40	0.50	-0.05	1.11	1.50	21	35	44

TABLE III

Coastal Dune Cores
Ø Values (Folk & Ward)

Sample No.	Depth in feet	Mean	Dev	SK	Kurt	Principal Mode *=Polymodal	% pre-mode	% Mode	% Post mode
60-CI-	0.7	1.65	0.52	+0.13	1.27	2.00	36	42	22
	2.2	1.64	0.38	+0.02	1.17	2.00	33	51	16
	7.0	1.55	0.40	-0.11	1.09	2.00	41	47	12
	10.0	1.53	0.46	+0.07	1.21	2.00	46	39	15
60-CC-	0.7	1.34	0.61	-0.15	1.10	2.00	57	31	12
	2.2	1.45	0.47	-0.12	1.01	2.00	51	38	11
	7.0	1.24	0.60	-0.14	0.98	1.50	34	30	36
	10.0	1.24	0.53	-0.06	1.01	1.50	33	34	33
61-CT-	2.0	2.07	0.65	+0.14	1.12	2.00	17	33	50
	3.0	1.42	0.68	+0.11	1.31	1.50	25	30	45
61-CI-	2.0	2.07	0.64	+0.14	1.11	2.00	17	33	50
	3.0	1.43	0.67	+0.12	1.30	1.50	24	30	46
61-CC-	2.0	----	----	-----	----	----	----	----	----
	3.0	1.34	0.87	+0.12	1.40	1.50	34	25	41
62-CT-	2.0	1.52	0.54	-0.12	1.11	2.00	45	39	16
	4.0	1.60	0.50	-0.09	1.05	2.00	39	41	20
	6.0	1.39	0.51	-0.09	1.03	2.00	56	34	10
	10.0	1.43	0.43	0.12	1.04	2.00	53	39	8
	13.0	1.47	0.80	-0.35	1.18	2.00	44	32	24
62-CI-	2.0	1.60	0.46	-0.05	1.11	2.00	38	44	18
	4.0	1.70	0.44	-0.03	1.09	2.00	30	46	24
	6.0	1.51	0.42	-0.02	0.99	2.00	47	41	12
	10.0	1.55	0.36	-0.02	1.09	2.00	43	47	10
	13.0	1.73	0.52	-0.21	1.18	2.00	29	40	31
62-CC-	2.0	1.32	0.67	-0.11	1.07	2.00	58	28	14
	4.0	1.48	0.54	-0.09	0.98	2.00	49	35	16
	6.0	1.28	0.56	-0.06	1.01	1.50	31	32	37
	10.0	1.35	0.46	-0.10	0.97	1.50	23	37	40
	13.0	1.20	0.94	-0.27	1.05	2.00	57	25	18
63-CT-	2.0	1.35	0.69	-0.10	1.13	2.00	56	29	15
	2.8	0.95	0.87	-0.06	1.42	1.00	25	28	47
	4.5	0.37	0.85	-0.02	1.08	1.00	55	24	21
	5.5	0.04	1.71	-0.29	1.74	0.50	46	17	37
63-CI-	2.0	1.52	0.53	-0.04	1.05	2.00	46	37	17
	2.8	1.33	0.67	-0.09	1.37	1.50	30	30	40
	4.5	1.13	0.69	+0.02	1.03	1.00	17	27	56
	5.5	1.27	0.93	-0.25	1.16	2.00	55	27	18
63-CC-	2.0	0.98	0.87	+0.06	1.20	1.00	26	26	48
	2.8	0.81	0.88	-0.04	1.57	1.00	31	32	37
	4.5	0.23	0.80	-0.05	1.09	0.50	37	24	39
	5.5	-0.46	1.78	-0.41	1.75	0.50	51	19	30
64-CT-	1.5	3.09	0.39	-0.19	2.01	3.50	39	53	8
	2.2	3.20	0.25	+0.08	1.02	3.50	25	64	11
	3.0	3.19	0.28	-0.02	1.03	3.50	23	65	12
	5.0	3.04	0.55	-0.36	2.09	3.50	40	49	11
64-CI-	1.5	3.09	0.37	-0.17	1.87	3.50	39	53	8
	2.2	3.20	0.26	+0.06	1.02	3.50	25	64	11
	3.0	3.21	0.29	-0.08	1.22	3.50	20	67	13
	5.0	3.15	0.41	-0.20	2.05	3.50	34	55	11
64-CC-	1.5	2.43	1.19	-0.52	1.10	3.50	57	31	12
	2.2	3.15	0.50	-0.16	1.58	3.50	31	50	19
	3.0	3.06	0.48	-0.18	1.67	3.50	43	45	12
	5.0	2.52	1.02	-0.50	1.56	3.00	36	31	33
66-CT-	2.0	1.94	0.33	-0.06	1.46	2.00	10	51	39
	6.0	1.79	0.73	-0.24	1.05	2.50	56	29	15
	6.8	-0.09	1.75	+0.26	0.86	-0.50*	35	15	50
	9.0	1.44	1.45	-0.62	0.66	2.50*	45	26	20

TABLE III

Coastal Dune Cores
Ø Values (Folk & Ward)

Sample No.	Depth in feet	Mean	Dev	SK	Kurt	Principal Mode *=Polymodal	% pre-mode	% Mode	% Post mode
66-CI-	2.0	1.95	0.29	+0.04	1.27	2.00	7	53	40
	6.0	1.97	0.59	-0.13	1.11	2.50	49	34	17
	6.8	1.80	0.92	-0.22	0.98	2.50	54	23	23
	9.0	2.41	0.57	-0.21	1.43	2.50	21	37	42
66-CC-	2.0	1.81	0.53	-0.29	1.48	2.00	22	44	34
	6.0	1.39	0.88	-0.11	0.84	2.00*	52	21	27
	6.8	-0.88	1.34	+0.14	1.41	-0.50	47	20	33
	9.0	0.39	1.48	+0.51	0.62	-0.50*	15	25	60
67-CT-	1.0	1.58	0.50	-0.11	1.09	2.00	40	41	19
	4.0	1.55	0.42	-0.02	1.06	2.00	43	43	14
	6.2	1.87	0.45	+0.04	1.09	2.00	79	44	37
	10.3	1.91	0.50	-0.12	1.31	2.00	18	39	43
	12.5	1.46	0.49	-0.20	1.07	2.00	49	41	10
	14.3	1.62	0.47	-0.13	1.12	2.00	36	44	20
67-CI-	1.0	1.65	0.45	-0.04	1.09	2.00	34	45	21
	4.0	1.62	0.40	+0.05	1.13	2.00	37	47	16
	6.2	1.92	0.43	+0.09	1.05	2.00	16	44	40
	10.3	1.98	0.44	+0.02	1.19	2.00	12	41	47
	12.5	1.56	0.40	-0.10	1.08	2.00	41	47	12
	14.3	1.70	0.40	-0.04	1.08	2.00	29	49	22
67-CC-	1.0	1.35	0.59	-0.13	1.01	2.00	56	31	13
	4.0	1.40	0.45	-0.05	0.92	1.50	21	35	44
	6.2	1.65	0.45	-0.06	1.05	2.00	34	44	32
	10.3	1.64	0.82	-0.42	1.59	2.00	33	36	31
	12.5	1.25	0.60	-0.17	0.98	2.00	62	30	8
	14.3	1.42	0.58	-0.18	1.05	2.00	51	35	14
68-CT-	1.0	1.49	0.59	-0.13	1.11	2.00	47	36	17
	3.0	1.61	0.53	-0.09	1.11	2.00	38	40	22
	5.5	1.68	0.49	-0.07	1.14	2.00	32	43	25
	9.0	1.59	0.53	-0.15	1.11	2.00	39	40	21
	12.0	1.42	0.48	-0.11	1.10	2.00	54	37	9
	14.5	1.57	0.51	-0.11	1.21	2.00	41	42	17
68-CI-	1.0	1.61	0.51	-0.03	1.10	2.00	39	40	21
	3.0	1.67	0.46	-0.06	1.08	2.00	33	44	23
	5.5	1.74	0.45	0	1.11	2.00	38	45	27
	9.0	1.67	0.47	-0.07	1.08	2.00	33	44	23
	12.0	1.47	0.45	-0.05	1.11	2.00	50	39	11
	14.5	1.63	0.46	0	1.17	2.00	37	44	19
68-CC-	1.0	1.12	0.70	-0.10	0.97	1.50	42	25	33
	3.0	1.40	0.68	-0.05	1.11	2.00	54	29	17
	5.5	1.46	0.61	-0.18	1.10	2.00	48	35	17
	9.0	1.33	0.66	-0.20	1.01	2.00	55	32	13
	12.0	1.24	0.57	-0.18	0.98	1.50	33	31	36
	14.5	1.38	0.65	-0.28	1.09	2.00	51	31	18
70-Ct-	0.2	1.63	0.62	+0.06	1.16	2.00	41	35	24
	1.0	1.78	0.59	+0.03	1.09	2.00	30	38	32
	2.0	0.49	1.14	-0.15	0.92	1.00	47	18	35
	3.0	1.33	0.83	-0.22	1.33	2.00	55	28	17
	4.0	1.33	0.83	-0.16	1.27	2.00	56	26	18
	4.5	0.40	1.69	-0.43	0.67	2.00*	67	18	15
70-CI-	0.2	1.70	0.60	+0.11	1.13	2.00	37	37	26
	1.0	1.84	0.56	+0.08	1.07	2.00	26	39	35
	2.0	1.18	0.73	-0.02	0.97	1.50	40	24	36
	3.0	1.53	0.62	-0.02	1.11	2.00	47	33	20
	4.0	1.51	0.65	+0.01	1.03	2.00	49	30	21
	4.5	1.65	0.66	+0.08	1.04	2.00	42	31	27
70-CC-	0.2	1.30	0.64	-0.07	1.05	1.50	31	29	40
	1.0	1.40	0.67	-0.12	1.11	2.00	53	30	17
	2.0	-0.13	1.05	+0.02	0.91	0	37	17	46
	3.0	0.60	1.16	-0.28	0.98	1.50	59	19	22
	4.0	0.68	1.04	-0.22	0.83	1.50*	56	20	24
	4.5	0.79	1.50	+0.42	0.83	-1.50*	21	22	57

TABLE III

Coastal Dune Cores
ϕ Values (Folk & Ward)

Sample No.	Depth in feet	Mean	Dev	SK	Kurt	Principal Mode	% pre-mode	% Mode	% Post mode
69-CT-	0.2	1.49	0.65	+0.11	1.13	1.50	23 -	30 -	47
	1.0	1.81	0.74	+0.03	1.05	2.00	33 -	32 -	35
	2.0	1.35	0.84	-0.02	1.00	2.00	56 -	24 -	20
	3.0	-0.33	2.57	-0.76	3.19	1.50*	38 -	30 -	32
	4.0	0.82	1.45	+0.13	0.73	0*	22 -	13 -	65
	4.5	-0.13	1.76	+0.20	0.77	-1.00*	25 -	12 -	63
69-CI-	0.2	1.56	0.65	+0.14	1.12	2.00	49 -	30 -	21
	1.0	1.89	0.69	+0.11	0.98	2.00	28 -	33 -	39
	2.0	1.57	0.77	+0.02	0.99	2.00	46 -	28 -	26
	3.0	1.45	0.50	+0.12	1.16	1.50	17 -	39 -	44
	4.0	1.76	1.08	-0.15	0.75	3.00*	68 -	23 -	9
	4.5	1.76	0.93	+0.04	0.83	2.00*	42 -	20 -	38
69-CC-	0.2	1.19	0.62	0	1.05	1.50	38 -	30 -	32
	1.0	1.23	0.92	-0.18	1.17	2.00	58 -	24 -	18
	2.0	0.79	0.87	0	1.06	1.00*	37 -	25 -	38
	3.0	-1.79	2.68	-0.02	0.47	-5.00*	0 -	32 -	68
	4.0	-0.13	1.02	+0.30	1.06	-0.50	18 -	24 -	58
	4.5	-1.06	1.27	+0.17	1.27	-1.00*	38 -	19 -	43
71-CT-	1.0	1.62	0.55	+0.08	1.20	2.00	40 -	39 -	21
	3.0	1.67	0.54	+0.05	1.18	2.00	35 -	41 -	24
	5.0	1.83	0.52	+0.09	1.11	2.00	25 -	43 -	32
	7.0	1.37	0.56	-0.07	0.99	2.00	56 -	32 -	12
	9.0	1.72	0.46	+0.02	1.18	2.00	29 -	46 -	25
	9.7	1.31	0.52	-0.04	1.00	1.50	28 -	33 -	39
71-CI-	1.0	1.68	0.54	+0.13	1.20	2.00	36 -	41 -	23
	3.0	1.72	0.52	+0.10	1.18	2.00	32 -	43 -	25
	5.0	1.87	0.50	+0.14	1.07	2.00	22 -	43 -	35
	7.0	1.45	0.52	-0.07	1.01	2.00	51 -	36 -	13
	9.0	1.75	0.45	+0.09	1.19	2.00	26 -	48 -	26
	9.7	1.38	0.48	-0.02	1.02	1.50	22 -	35 -	43
71-CC-	1.0	1.30	0.54	-0.04	1.01	1.50	29 -	34 -	37
	3.0	1.37	0.60	-0.07	1.01	1.50	27 -	29 -	44
	5.0	1.56	0.56	-0.05	1.04	2.00	43 -	36 -	21
	7.0	1.05	0.61	+0.01	0.94	1.00	19 -	29 -	52
	9.0	1.50	0.52	-0.09	0.[illegible]9	2.00	47 -	37 -	16
	9.7	1.01	0.58	+0.05	0.97	1.00	19 -	33 -	48

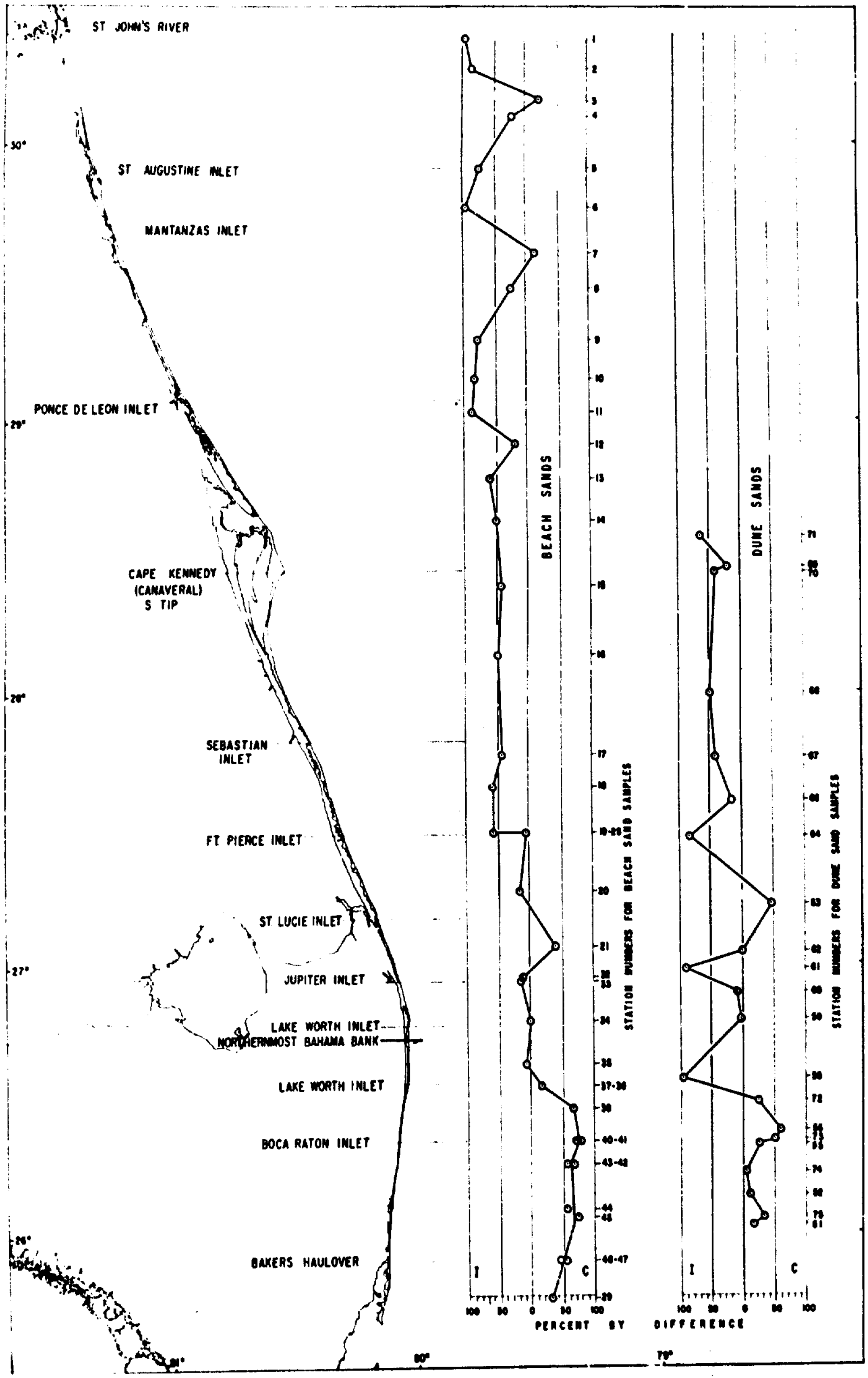

Figure 9. Percent by difference of carbonate to insolubles vs. beach and dune sample location. Percent by difference has been used to evaluate progressive changes between samples. This method of manipulating the data results in an artificial value characterizing excess or deficiency in insoluble material with distance along shoreline. Specifying the percentage of insoluble materials (for all practical purposes consisting of quartz) as positive in value and the acid soluble fraction (carbonate) as negative, the influence of one constituent upon the other can be visualized more readily by graphic techniques. Thus, when the weight of these two constituents are equal the percent by difference would be equal to zero. An excess of carbonate would provide a negative value and an excess of silica would provide a positive value.

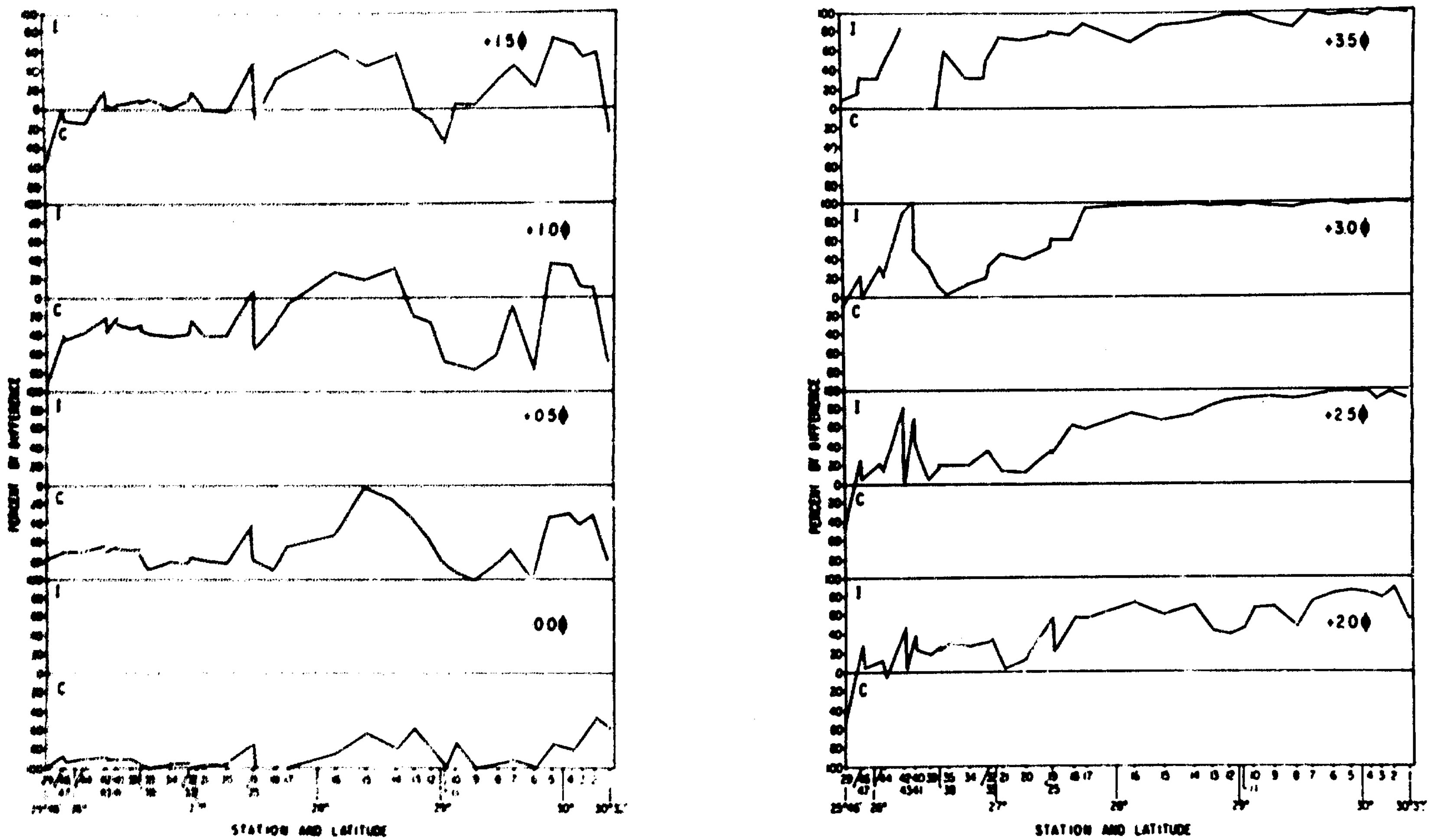

Figure 10. Perce.t by difference of carbonates to insols vs. phi grain size. Percent by difference has been used to evaluate progressive changes between samples. This method of manipulating the data results in an artificial value characterizing excess or deficiency in insoluble material with distance along shoreline. Specifying the percentage of insoluble materials (for all practical purposes consisting of quartz) as positive in value and the acid soluble fraction (carbonate) as negative, the influence of one constituent upon the other can be visualized more readily by graphic techniques. Thus, when the weight of these two constituents are equal the percent by difference would be equal to zero. An excess of carbonate would provide a negative value and an excess of silica would provide a positive value.

TABLE IV

BRIEF SAMPLE DESCRIPTION

FLORIDA STRAITS

Sample No.	Water Depth	Latitude	Longitude	Sampler	Description
1. MG 63-5	2.5 fms (4.6 m)	25°44'	80°12'	Orange Peel Grab	(Med. Crs. Bioclastic sand)
2. MG 63-6	250-270 m	25°44'	80°01'	Gravity Corer - 2" Orange Peel Grab	(A. No recovery w/Orange Peel B. One 6" and one 12" core of very fine sand and silty clay)
3. MG 63-7	360 m	25°45'	79°56'	Gravity Corer - 2"	(2" of carb sand w/s phos granules)
4. MG 63-8	420 m	25°45'	79°50'	Gravity Corer - 2"	(2" of carb sand)
5. MG 63-9	445 fms (832 m)	25°45'	79°45'	Gravity Corer - 2"	(5-10 grms of carb sand)
6. MG 63-10	230 fms (420 m)	26°00'	79°49'	Gravity Corer - 2"	(1-2 gms of carb sand)
7. MG 63-11	139 fms (252 m)	26°00'	80°00'	Gravity Corer - 2"	(Few gms of carb sand w/black rock frags to 1/4")
8. MG 63-12	234 m	26°00'	80°00'	Gravity Corer - 2"	(Few sand grains)
9. MG 63-13	98 fms (180 m)	26°00'	80°05'	Gravity Corer - 2"	(6" of silty sand w/a few shells)
10 MG 63-14	73 fms (126 m)	26°15'	80°03'	Gravity Corer - 2"	(6" of fine sand)
11. MG 63-15	130 fms (238 m)	26°15'	79°58'	Gravity Corer - 2"	(Few gms of carb sand)
12. MG 63-16	130 fms (290 m)	26°15'	79°52'	Gravity Corer - 2"	(Few gms of fine sand)
13. MG 63-17	262 fms (480 m)	26°14'	79°47'	Gravity Corer - 2"	(2 gms of carb sand)
14. MG 63-18	310 fms (580 m)	26°15'	79°42'	Gravity Corer - 2"	(Short core of muddy sand and silt)
15. MG 63-19	295 fms (540 m)	26°30'	79°41'	Gravity Corer - 2"	(Short core of muddy silty sand.)
16. MG 63-20	240 fms (440 m)	26°30	79°46'	Gravity Corer - 2"	(Short core of muddy silt and sand)
17. MG 63-21	198 fms (362 m)	26°30'	79°51'	Gravity Corer - 2"	(Small amount of sand)
18. MG 63-22	140 fms (256 m)	26°30'	79°53'	Gravity Corer - 2"	(Small amount of sand)
19. MG 63-23	75 fms (137 m)	26°30'	80°02'	Gravity Corer - 2"	(Two - 1.2" and 4" of muddy sand)
20. MG 63-24	50 fms (90 m)	26°45'	79°38'	Gravity Corer - 2"	(Very small amount of bioclastic silty sand)
21. MG 63-25	220 m	26°45'	79°34'	Gravity Corer - 2"	(No recovery - hard bottom)
22 MG 63-26	180 fms (330 m)	26°45'	79°49'	Gravity Corer - 2"	(No recovery - hard bottom)
23. MG 63-27	235 fms (430 m)	26°45'	79°44'	Gravity Corer - 2"	(Very small amount of sand)
24 MG 63-28	17 fms (31 m)	27°00'	80°01'	Orange Peel Grab	(Grey, med. crs. sand)
25. MG 63-29	102 fms (186 m)	27°00'	79°55'	Gravity Corer - 2"	(Short core of muddy sand w/some shells)
26. MG 63-30	57 fms (104 m)	27°15	79°55'	Gravity Corer - 2" Orange Peel Grab	(A. No recovery w/O.P. Grab. B. Small amount of sand recovered with G. C.)

of sand could be accounted for easily by the measured thickness of unconsolidated sediment resting there.

Abrasion Tests

Abrasion tests conducted on naturally occuring mixtures of shell and quartzose sand did not indicate appreciable wear of the shell material. In fact, a calculated 600 nautical miles of travel did not produce sufficient abrasive loss to be detected by sieving tests of grain size changes because sieving errors are experimentally determined to be greater than the change in weight of the abraded sample before and after abrasion. Physical breakdown of shell fragments by means other than "beach wear" are possible (Purdy, 1963) but biological and other breakdown methods could not be evaluated here because of experimental and time limitations. It is not believed by the present writers that such breakdown and grinding of shell to a fine silt or clay fraction has any large role in the sand loss under consideration by this project.

Radiocarbon Assay

It is a well established fact that sea level has been raised and lowered several times in the past by the growth and decay of continental glaciation. Sea level has been as much as 400 feet (120 meters) below present day sea level about 20,000 years ago (see Figure 11; also Shepard, 1963; Scholl, 1964). Since that time it has risen very rapidly up to about 7,000 years ago when the sea rose more gradually to present day level. We can therefore tentatively consider that (A) all shell additions to the present day beach are either mixtures of contemporaneous shells and very old shells, or (B) shell additions to the present beach are a mixture of contemporary shells and relatively young shells which are probably not more than 7,000 years of age admixed with very old shells. Evaluation of the relative contributions of each requires certain assumptions. The assumption of "old shells" would have to be based ideally on the premise that the material is older than could be detected by radiocarbon activity measurements. Because the Anastasia is about one hundred thousand years old and beyond the detection limits of radiocarbon, the samples of this shell would be radioactively "dead" for all practical purposes (i.e., they would contain no measureable or detectable carbon 14 activity). The reasons for assuming that shells older than 7,000 years would not likely be present on the beach (in any serious quantities) are that large quantities of sediment apparently do not occur offshore to be reworked shoreward (Report of Alpine Geophysical, U.S. Army Engineers, 1963), and if they did occur in large quantities they would probably not be involved in the nourishment of the beach if they occurred at water depths greater than 30 feet [cf. previous discussion, see also figure 3 for populations common to this zone (Bernard et al, 1962)].

Knowing the activity of contemporaneous shell and comparing it with the activity of a given beach sample, it is then a simple procedure

to relate this ratio (by appropriate curves) to the relative contribution of several admixtures, or combinations of shell, to provide a similar activity ratio in terms of present recent carbonate contributed. We have measured the activity of the shell carbonate from the Anastasia and find it to be radioactively dead; i.e., no detectable radiocarbon. We have also measured the activity of modern shells from the same environment and can therefore construct a working curve, as shown in Figure 12. The precision with which we can thus estimate the relative contribution of the several combinations of new and old shell leaves something to be desired for samples with a high activity, or those containing more than 50% new carbon, but improves logarithmically (because of the half life) with smaller contributions from new carbon sources.

Within practical limits it is now possible to estimate the relative proportions of the various combinations of shell ages contributed to the beach sediments. Our first beach sand sample was measured for activity and found to have an activity equivalent to 0.5 approximately. According to our working curve, this would indicate that about 50% or more of the shell in the beach sediment consists of relatively new shell. If the activity measured had been 0.05 instead of 0.5, then only about 5% to 12% of the beach shell could consist of material with ages between 7,000 years to present day. In such a case, the beach sediment would consist largely of eroded outcrop shells rather than more recent additions from living populations .

The results of our analyses are summarized in Table V. Here it can be seen that as little as 20% of the total shell content near Cape Kennedy is new shell, but near Miami as much as 50% to 60% of the total may be new shell.

CONCLUSIONS

1. Study of shoreline deposits from Cape Kennedy to Miami indicates a gradual progressive increase in carbonate content from north to south progressing at a rate of 2% per 10 miles of shoreline.

2. New and old shell is not adequately distinguished in beach sands by paleontological techniques based on species abundance or variations.

3. New shell cannot be distinguished quantitatively from old shell contributions to beaches through erosion by the use of weathering criteria such as staining and corrosion of shells.

4. It may be possible to evaluate relative contributions of new and old shell to beaches by mineralogical variations but sufficient mineralogical differences in the carbonate fraction are not to be expected because of the natural variations in mineralogy

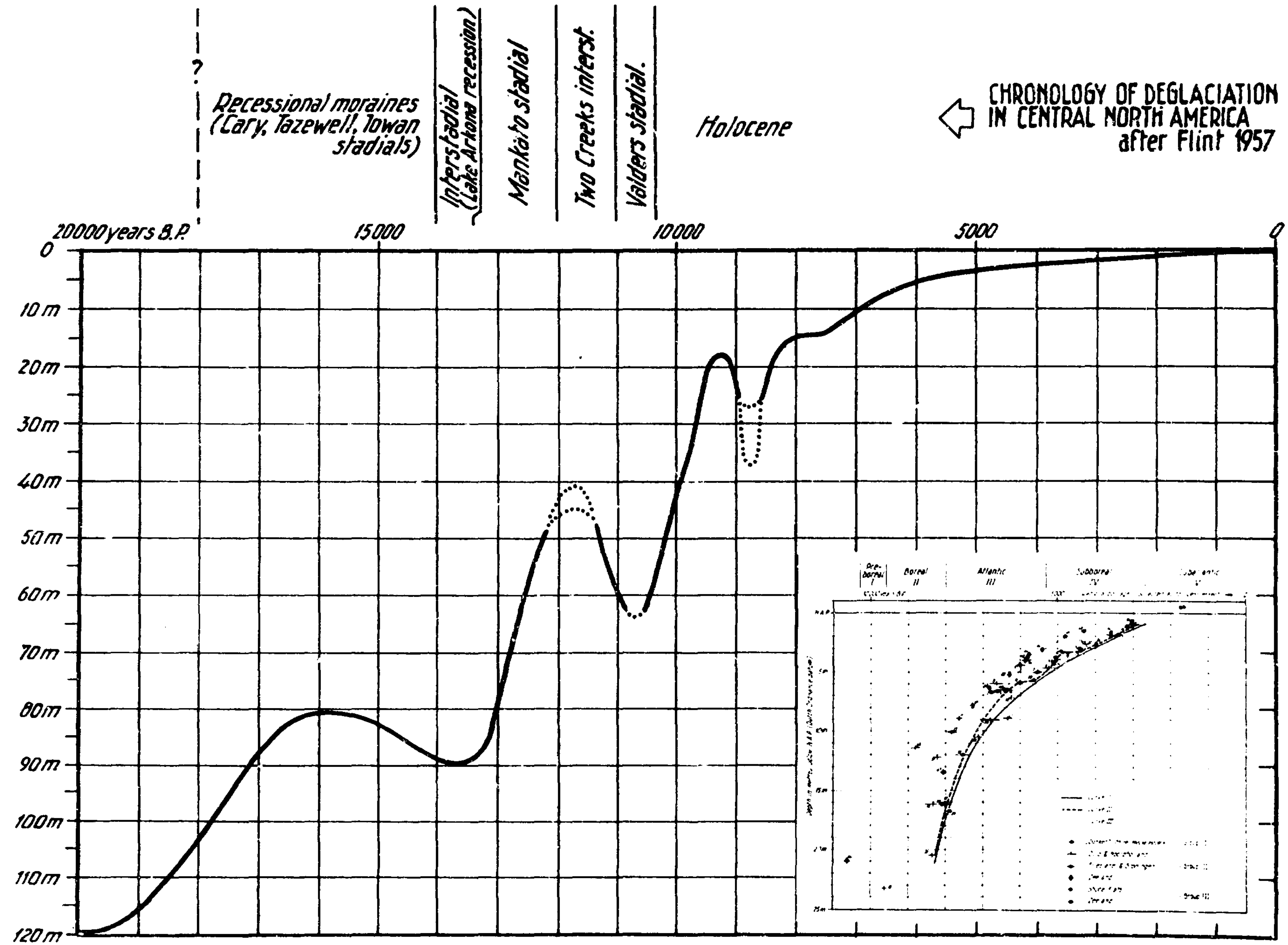

Figure 11. Sea level rise vs. time. (After Shepard, 1960; Jelgersma, 1961; Scholl, 1964).

Example:
Activity of sample = 0.2
Therefore: sample contains 80% outcrop material and 20% contemporaneous material, or, sample contains 52% outcrop material and 48% material which is 7000 yrs. old.
Conclusion: only approximately 34± 14% of the shell material is relatively young and 66± 14% is derived by erosion of outcroping Anastasia fm.

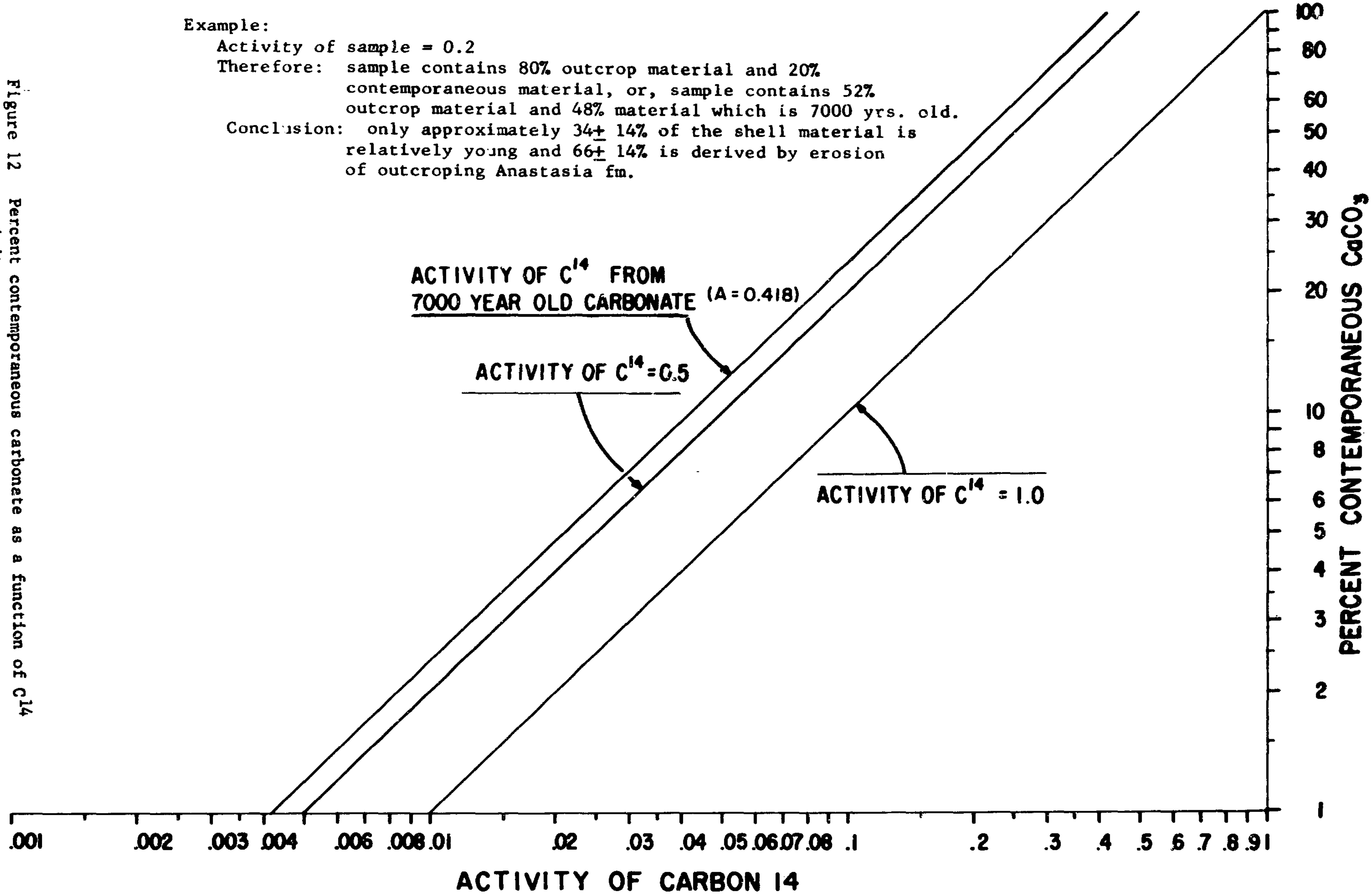

Figure 12 Percent contemporaneous carbonate as a function of C^{14} activity.

TABLE V

ADMIXTURES OF YOUNG AND OLD SHELL

Sample 54

Activity = .2814

Therefore: 1) Sample contains only 28% contemporaneous material and the balance (72%) is derived from very old outcrop sources.

2) Sample contains as much as 68% material which is 7,000 years old and the balance (32%) is derived from very old outcrop sources.

37-63% or approx. 35-60% new shell present

Conclusion: Only about 50 $\pm$ (3σ = 20%; 1σ = $\pm$ 13%) of the carbonate fraction is derived from a relatively recent source of supply. The balance is derived from Anastasia fm. outcrops or equivalent. Probably as little as 30 but not more than 40% of the carbonate is locally derived from growing organisms.

Sample 57

Activity = .3265

Therefore: 1) Sample contains only 33% contemporaneous material and the balance (67%) is derived from very old outcrop sources.

2) Sample contains as much as 79% material which is 7,000 years old and the balance (21%) is derived from very old outcrop sources.

41-71% or approx. 40-70% new shell present

Conclusion: Only about 56$\pm$ (3σ = 23%; 1σ = $\pm$ 15%) of the carbonate fraction is derived from a relatively recent source of supply. The balance is derived by erosion of Anastasia fm. outcrops or equivalent. Probably as little as 40 but not more than 70% of the carbonate is locally derived from growing organisms.

Sample 65

Activity = .372

Therefore: 1) Sample contains only 40% contemporaneous material and the balance (60%) is derived from very old outcrop sources.

2) Sample contains as much as 90% material which is 7,000 years old and the balance (10%) is derived from very old outcrop sources.

48-72% or approx. 45-70% new shell present

Conclusion: Only about 65 $\pm$ (3σ = 25%; 1σ = $\pm$ 17%) of the carbonate fraction is derived from a relatively recent source of supply. The balance is derived by erosion of Anastasia fm. outcrops or equivalent. Probably as little as 45 but not more than 70% of the carbonate is locally derived from growing organisms.

Sample 71

Activity = .178

Therefore: 1) Sample contains only 17% contemporaneous material and the balance (83%) is derived from very old outcrop sources.

2) Sample contains as much as 41% material which is 7,000 years old and the balance (59%) is derived from very old outcrop sources.

21-37% or approx. 20-35% new shell present

Conclusion: Only about 29 $\pm$ (3σ = 12%; 1σ = $\pm$ 8%) of the carbonate fraction is derived from a relatively recent source of supply. The balance is derived by erosion of Anastasia fm. outcrops or equivalent. Probably as little as 20 but not more than 35% of the carbonate is locally derived from growing organisms.

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inherent in hard parts of various carbonate secreting species.

5. Radiocarbon assays of collected beach sands appear to provide quantitative analyses of the relative contribution of new and old shell to a beach with a high precision where large amounts of old shell are contributed to a beach through erosion or along-shore drift.

6. With adequate numbers of samples evaluated for new and old shell, it may be possible in future studies of this area to evaluate more precisely the relative contribution of new and old shell to large segments of the coast.

7. Detailed sampling on a grid system is needed to provide materials for these specific segments to arrive at a solution to the problem of new and old shell contributions.

8. Practical evaluation of shell loss, as well as addition or transportation, is possible by the assay of natural carbon 14 in samples from selected areas on the shoreline, shelf and slopes flanking the Florida East Coast. Naturally-tagged carbonates may thus uniquely describe the factors involved in the basic research problem of beach erosion and nourishment.

9. The history of calcium carbonate destruction or disintegration may be developed by radiocarbon assay as well. This could provide sufficient insight into the transportation losses and abrasional losses of shell within an area such as the Florida East Coast.

10. The results of the assays conducted in the present study indicate that the present sources of new shell indigenous to the areas of sand loss obviously cannot keep up with sand loss.

11. The physical factors responsible for sand loss between Lake Worth Inlet and Miami are such that lost sand cannot be easily recovered or dammed to prevent loss of beaches.

12. Artificial nourishment procedures should not depend upon large quantities of shell sand to be generated locally by indigenous carbonate secreting organisms.

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APPENDIX A

Quarterly Progress Report No. 1
1 February 1964 to 1 May 1964

to

Coastal Engineering Research Center
U. S. Army Corps of Engineers
DA-49-055-CIV-ENG 64-8

1.0 INTRODUCTION

1.1 Purpose of the Project

The purpose of this program is to seek answers to the following questions in order to design a remedial program of natural or artificial beach nourishment.

1. Is the present beach shell composed of recent shell or old shell or of both and in what proportion?

2. If new shell, at what rate is the shell coming into existence to replenish the beaches?

3. If old shell, is the source offshore? from the eroded beach face? or from the weathering of the coquina?

4. In what way is the beach shell lost to the beaches at the present high rate? by dissolving into the sea water? by grinding into powder? or by moving offshore?

5. Is there any indication that the silica sand component of the beach tends to remain on the beach longer than the shell?

1.2 Review of Previous Work

This phase of the program was preceded by a preliminary phase which evaluated the sampling and testing procedures and was reported by Rusnak and Hofmann in January 1964 in a report to the Coastal Engineering Research Center.

1.3 First Quarterly Progress Report

Section Two of this first quarterly progress report will describe the progress made to date. Section Three will include the plans for the next quarter.

2.0 PROGRESS

2.1 General

Sieve analyses were made on a series of samples at approximately ten mile intervals starting in the vicinity of Jacksonville and progressing south to the vicinity of Hobe Sound, Florida.

2.20 Sieve Analyses

The following IBM Printouts give the results of computations which derived the descriptive parameters of median, mean, skewness, deviation (or sorting) and kurtosis.

The sample number without a letter symbol represents the total sample. Sample numbers designated by the letter "A" is the insoluble residue derived from the total sample by digesting the sample in hydrochloric acid to remove the carbonate fraction. The sample number designated by the letter "C" is the weight percentages of the carbonate fraction obtained by difference and the descriptive parameters calculated.

The size distribution of shell in samples 2, 5 and 11 is largely restricted to the largest size grade represented, i.e., a meaningful distribution is not obtainable by difference and is not entered.

2.21 CUMULATIVE WEIGHT PERCENTAGES

SAMPLE	PERCENTILES				
NUMBER	5	16	50	84	95
1	1.76	2.29	2.81	3.15	3.36
1A	1.98	2.35	2.81	3.14	3.35
1C	-1.70	.59	1.61	2.57	3.25
2	-.15	2.10	2.67	2.98	3.14
2A	1.87	2.25	2.71	2.98	3.15
3	-1.87	-1.12	-.28	1.71	2.43
3A	-.49	.16	1.60	2.38	2.69
3C	-2.35	-1.34	-.67	.10	.73
4	-1.86	-.70	1.29	2.43	2.77
4A	.42	1.01	2.00	2.55	2.75
4C	-2.70	-1.48	-.50	.55	1.25
5	0.00	.90	1.85	2.52	2.79
5A	.79	1.27	2.00	2.53	2.75

Appendix A(contd.)

SAMPLE NUMBER	PERCENTILES 5	16	50	84	95
6	1.92	2.25	2.63	2.91	3.07
6A	1.95	2.25	2.64	2.90	3.08
6C	-.12	.75	1.96	2.93	3.26
7	-1.52	-.84	.56	1.96	2.52
7A	.44	.95	1.70	2.40	2.75
7C	-1.82	-1.18	-.30	.66	1.30
8	-.26	.38	1.55	2.28	2.58
8A	.95	1.34	1.91	2.42	2.68
8C	-.59	-.18	.59	1.32	1.85
9	1.36	1.84	2.40	2.71	2.92
9A	1.62	1.95	2.42	2.76	2.95
9C	.65	.95	1.59	2.27	2.78
10	1.48	2.08	2.67	2.98	3.19
10A	1.77	2.20	2.72	2.99	3.12
10C	-.22	.69	1.49	2.39	2.98
11	1.90	2.38	2.75	3.04	3.21
11A	2.15	2.45	2.77	3.05	3.24
12	-.89	-.23	2.33	2.88	3.09
12A	.56	2.05	2.65	2.95	3.13
12C	-1.45	-.84	-.13	.85	1.85
13	-.31	.75	2.55	2.89	3.02
13A	.90	2.14	2.67	2.93	3.04
13C	-1.51	-.55	.35	1.91	2.62
14	.31	.74	1.35	1.92	2.41
14A	.54	.89	1.43	2.00	2.50
14C	-.07	.33	.97	1.65	2.06
15	.03	.71	1.47	2.18	2.60
15A	.42	.91	1.62	2.26	2.66
15C	-.60	.08	1.00	1.86	2.30
16	.89	1.23	1.75	2.20	2.50
16A	.98	1.28	1.77	2.23	2.50
16C	.45	.92	1.54	2.13	2.46
17	.94	1.38	1.89	2.37	2.78
17A	1.13	1.47	1.92	2.41	2.77
17C	.41	1.06	1.75	2.26	2.57

Appendix A(contd.)

SAMPLE NUMBER	5	16	PERCENTILES 50	84	95
18	1.18	1.75	2.37	2.90	3.23
18A	1.44	1.84	2.38	2.93	3.28
18C	.25	1.19	2.20	2.79	3.05
19	.95	2.15	2.97	3.35	3.61
19A	1.69	2.54	3.05	3.40	3.65
19C	-.68	.62	2.37	3.08	3.38
20	.27	.86	2.25	3.12	3.38
20A	.89	1.42	2.69	3.25	3.42
20C	-.17	.42	1.40	2.73	3.05
21	-1.34	-.25	.84	1.28	2.45
21A	.48	.75	1.16	1.[illegible]	3.03
21C	-1.70	-.57	.66	1.10	1.56

Appendix A(contd.)

2.22 DESCRIPTIVE PARAMETERS

SAMPLE NUMBER	PHI MEDIAN DIA.	PHI DEV. MEAS.	PHI MEAN DIA. PERCENTILES 16-84	5-95	SKEWNESS PERCENTILES 16-84	5-95	KURTOSIS
1	2.810	.430	2.720	2.560	-.209	-.581	.860
1A	2.810	.395	2.745	2.665	-.164	-.367	.734
1C	1.610	.990	1.580	.775	-.030	-.843	1.500
2	2.670	.440	2.540	1.495	-.295	-2.670	2.738
2A	2.710	.365	2.615	2.510	-.260	-.547	.753
3	-.280	1.415	.295	.280	.406	.395	.519
3A	1.600	1.110	1.270	1.100	-.297	-.450	.432
3C	-.670	.720	-.620	-.810	.069	-.194	1.138
4	1.290	1.565	.865	.455	-.271	-.533	.479
4A	2.000	.770	1.780	1.585	-.285	-.538	.512
4C	-.500	1.015	-.465	-.725	.034	-.221	.945
5	1.850	.810	1.710	1.395	-.172	-.561	.722
5A	2.000	.630	1.900	1.770	-.158	-.365	.555
6	2.630	.330	2.580	2.495	-.151	-.409	.742
6A	2.640	.325	2.575	2.515	-.200	-.384	.738
6C	1.960	1.090	1.840	1.570	-.110	-.357	.550
7	.560	1.400	.560	.500	0.000	-.042	.442
7A	1.700	.725	1.675	1.595	-.034	-.144	.593
7C	-.300	.920	-.260	-.260	.043	.043	.695
8	1.550	.950	1.330	1.160	-.231	-.410	.494
8A	1.910	.540	1.880	1.815	-.055	-.175	.601
8C	.590	.750	.570	.630	-.026	.053	.626
9	2.400	.435	2.275	2.140	-.287	-.597	.793
9A	2.420	.405	2.355	2.285	-.160	-.333	.641
9C	1.590	.660	1.610	1.715	.030	.189	.613
10	2.670	.450	2.530	2.335	-.311	-.744	.900
10A	2.720	.395	2.595	2.445	-.316	-.696	.708
10C	1.490	.850	1.540	1.380	.058	-.129	.882
11	2.750	.330	2.710	2.555	-.121	-.590	.984
11A	2.770	.300	2.750	2.695	-.066	-.250	.816
12	2.330	1.555	1.325	1.100	-.646	-.790	.279
12A	2.650	.450	2.500	1.845	-.333	-1.788	1.855
12C	-.130	.845	.005	.200	.159	.390	.952

Appendix A(contd.)

SAMPLE NUMBER	PHI MEDIAN DIA.	PHI DEV. MEAS.	PHI MEAN DIA. 16-84	PERCENTILES 5-95	SKEWNESS 16-84	PERCENTILES 5-95	KURTOSIS
13	2.550	1.070	1.820	1.355	-.682	-1.116	.556
13A	2.670	.395	2.535	1.970	-.341	-1.772	1.708
13C	.350	1.230	.680	.555	.268	.166	.678
14	1.350	.590	1.330	1.360	-.033	.016	.779
14A	1.430	.555	1.445	1.520	.027	.162	.765
14C	.970	.660	.990	.995	.030	.037	.613
15	1.470	.735	1.445	1.315	-.034	-.210	.748
15A	1.620	.675	1.585	1.540	-.051	-.118	.659
15C	1.000	.890	.970	.850	-.033	-.168	.629
16	1.750	.485	1.715	1.695	-.072	-.113	.659
16A	1.770	.475	1.755	1.740	-.031	-.063	.600
16C	1.540	.605	1.525	1.455	-.024	-.140	.661
17	1.890	.495	1.875	1.860	-.030	-.060	.858
17A	1.920	.470	1.940	1.950	.042	.063	.744
17C	1.750	.600	1.660	1.490	-.150	-.433	.800
18	2.370	.575	2.325	2.205	-.078	-.286	.782
18A	2.380	.545	2.385	2.360	.009	-.036	.688
18C	2.200	.800	1.990	1.650	-.262	-.687	.750
19	2.970	.600	2.750	2.280	-.366	-1.150	1.216
19A	3.050	.430	2.970	2.670	-.186	-.883	1.279
19C	2.370	1.230	1.850	1.350	-.422	-.829	.650
20	2.250	1.130	1.990	1.825	-.230	-.376	.376
20A	2.690	.915	2.335	2.155	-.387	-.584	.382
20C	1.400	1.155	1.575	1.440	.151	.034	.393
21	.840	.765	.515	.555	-.424	-.372	1.477
21A	1.160	.610	1.360	1.755	.327	.975	1.090
21C	.660	.835	.265	-.070	-.473	-.874	.952

2.3 Interpretation of Results

It is observed that wide excursions of parameters from normal trends occur at and down current (littoral) from outcrops of the Anastasia formation. This indicates that either: outcrop erosion is an important contribution of beach material or that the resistant nature of the outcrops causes perturbations in the beach material that require investigations. The foregoing is in accordance with previous radio-carbon determinations.

3.0 FUTURE PROGRESS

3.1 Extension of Analyses

Sampling of beach sands will be continued from Lake Worth Inlet south to Miami Ship Channel. Those samples collected at ten mile intervals will be sieved in the immediate future in order to complete the analyses for basic data from Jacksonville Beach to Miami Ship Channel.

Samples collected relative to inlets and to both subaerial and submarine rock outcrops will then be analyzed in order to investigate their influence on the descriptive parameters of the sediment.

It is anticipated that the relative contributions of new shell and old shell will be determined by means of radiocarbon analyses.

3.2 Other courses

Displacement of sand in volumes large enough to be detected by comparison of changes in bathymetric contours of the same area at different times may be detected by our planned program of matching hydrographic survey charts. Amounts and directions of movement may then be computed. This will be supplemented by a diving program and tracer work, especially in those areas of deeper water where information is lacking and where sediment movement is at its slowest, demanding more precise measurement.

Appendix A(contd.)

3.0 FUTURE PROGRESS

3.1 Extension of Analyses

Sampling of beach sands will be continued from Lake Worth Inlet south to Miami Ship Channel. Those samples collected at ten mile intervals will be sieved in the immediate future in order to complete the analyses for basic data from Jacksonville Beach to Miami Ship Channel.

Samples collected relative to inlets and to both subaerial and submarine rock outcrops will then be analyzed in order to investigate their influence on the descriptive parameters of the sediment.

It is anticipated that the relative contributions of new shell and old shell will be determined by means of radiocarbon analyses.

3.2 Other courses

Displacement of sand in volumes large enough to be detected by comparison of changes in bathymetric contours of the same area at different times may be detected by our planned program of matching hydrographic survey charts. Amounts and directions of movement may then be computed. This will be supplemented by a diving program and tracer work, especially in those areas of deeper water where information is lacking and where sediment movement is at its slowest, demanding more precise measurement.

APPENDIX B

Quarterly Progress Report No. 2
1 May 1964 to 1 August 1964

to

Coastal Engineering Research Center
U. S. Army Corps of Engineers
DA-49-055-CIV-ENG 64-8

1.0 INTRODUCTION

1.1 Purpose of the Project

The purpose of this program is to seek answers to the following questions in order to design a remedial program of natural or artificial beach nourishment.

1. Is the present beach shell composed of recent shell or old shell or of both and in what proportion?
2. If new shell, at what rate is the shell coming into existence to replenish the beaches?
3. If old shell, is the source offshore? from the eroded beach face? or from the weathering of the coquina?
4. In what way is the beach shell lost to the beaches at the present high rate? by dissolving into the sea water? by grinding into powder? or by moving offshore?
5. Is there any indication that the silica sand component of the beach tends to remain on the beach longer than the shell?

1.2 Review of Previous Work

A series of detailed sediment analyses were performed and reported in the previous (first) quarterly report. These analyses included the Inman parameters of sorting, skewness and kurtosis of beach sands from Jacksonville to Hobe Sound, Florida.

1.3 Second Quarterly Progress Report

Section Two of this second quarterly progress report will describe the progress made to date. Section Three will include the plans for the next quarter.

2.0 PROGRESS

2.1 General

A series of samples were collected at ten mile (nominal) intervals from Lake Worth Inlet to the Miami Ship Channel. In most cases samples were collected in pairs, one on either side of an inlet. The sieve analyses of these samples is presently underway. This completes the second series of samples that was begun at Hobe Sound and forms a complete series from Jacksonville to Miami.

Five Samples of Anastasia formation outcrops between Anastasia Island and Jupiter Inlet were analyzed for insoluble residue.

A representative beach sand sample was subjected to an abrasion test to measure abrasion losses of a silica and carbonate sand mixture. The calculated travel of the average sand grain in the test was 267 miles (232 nautical miles) in this test.

A computer program for calculating the various parameters of the particulate materials under study is being adapted to the computer installation of the Institute of Marine Science.

2.2 Results

The insoluble fraction of the Anastasia formation, predominantly silica, was found to vary from 6.7% to 24.0% (by weight) of the total rock.

The generation of extremely fine debris products (clay size?) was on the order of 500 parts per million by weight of the original total sample in the 267 mile abrasion test. This sample is currently being studied to determine if a selectivity of abrasion of size and/or composition is defectable in the $> 62\ \mu$ sizes.

2.3 Interpretation

If the Anastasia formation is a significant source of beach material then the contribution percentages of the carbonate-silica sand to the modern beach has changed significantly from Anastasia time, the modern sands in the areas of Anastasia outcrop being 40-60 instead of 93-7 to 76-24 as it is in the Anastasia.

3.0 FUTURE PROGRESS

3.1 Abrasion Tests

Abrasion testing of larger shell fragments (new shell) and Anastasia formation is either underway or projected in the coming quarter.

Sites for radiocarbon beach sand samples are being chosen and will be collected for radiocarbon analyses.

Appendix B(contd.)

Erosion of coastal material (beaches, dunes and soils) supplies beach sand sizes as well as smaller sizes. Sites are being selected for borings that will yield information on the volume ratios of beach sand sizes to smaller materials that are available as erosion products.

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APPENDIX C

Quarterly Progress Report No.3
1 August 1964 to 1 November 1964

to

Coastal Engineering Research Center
U. S. Army Corps of Engineers
DA-49-055-CIV-ENG 64-8

1.0 INTRODUCTION

1.1 Purpose of the Project

The purpose of this program is to seek answers to the following questions in order to design a remedial program of natural or artificial beach nourishment.

1. Is the present beach shell composed of recent shell or old shell or of both and in what proportion?

2. If new shell, at what rate is the shell coming into existence to replenish the beaches?

3. If old shell, is the source offshore? from the eroded beach face? or from the weathering of the coquina?

4. In what way is the beach shell lost to the beaches at the present high rate? by dissolving into the sea water? by grinding into powder? or by moving offshore?

5. Is there any indication that the silica sand component of the beach tends to remain on the beach longer than the shell?

1.2 Review of Previous Work

A series of detailed sediment analyses were performed and reported in the first two quarterly reports. These analyses included the Inman parameters of sorting, skewness, and kurtosis of beach sands from Jacksonville to Hobe Sound, Florida.

1.3 Third Quarterly Progress Report

Section two of this third quarterly progress report will describe the progress made to date. Section Three will include the plans for the next quarter.

2.0 PROGRESS

2.1 General

Beach samples collected from Lake Worth Inlet to Miami Beach, Florida were sieved and the data needed for computing the Inman sediment parameters were obtained.

A beach sample was put to an abrasion test equivalent to 600 miles of travel.

Ninety-nine dune samples were collected from boring sites located between Miami Beach and False Cape, Cape Kennedy. These ninety-nine samples represent cross-sections of material available as erosion products.

Four beach samples collected between Miami beach and Cape Kennedy are now being assayed for C_{14} activity.

Five splits from the same sample were sieved and the weights of each separate split were compared in order to determine the range of variation in our analyses.

Sieves being used in the 1000 micron to 62 micron range were calibrated with glass beads obtained from the Bureau of Standards.

2.2 Results

After 600 miles of abrasion the original 1824 grams of beach sand was reduced to 1801 grams. The 23 grams abraded appeared to be clay size material.

The results of comparative sieving are shown in the tables 1 and 2.

Table 1
Sample #BEB 50
Total Sample

		Percentage				
Diameter in	Diameter in mm.	A	B	C	D	E
-1.5 to -1.0	2.83 - 2.00	0.5	0.4	0.3	0.6	0.3
-1.0 to -0.5	2.00 - 1.41	0.9	0.8	1.1	0.8	0.9
-0.5 to 0.0	1.41 - 1.00	2.6	2.5	2.7	2.5	2.8
0.0 to 0.5	1.00 - 0.707	6.5	7.0	6.7	7.2	7.5
0.5 to 1.0	0.707- 0.500	18.6	18.1	18.1	18.3	18.9
1.0 to 1.5	0.500- 0.354	31.3	31.8	31.8	31.3	31.5
1.5 to 2.0	0.354- 0.250	32.7	32.3	32.5	32.4	31.5
2.0 to 2.5	0.250- 0.177	4.9	5.1	5.0	5.0	4.9
2.5 to 3.0	0.177- 0.125	1.6	1.7	1.7	1.6	1.5
3.0 to 3.5	0.125- 0.088	0.3	0.[illegible]	0.2	0.3	0.2
3.5 to 4.0	0.088- 0.0625	0.0	0.0	0.0	0.0	0.0

Appendix C(contd.)

Table 2
Sample #BEB 50
Insoluble Residue Percentage

Diameter in ϕ	Diameter in mm.	A	B	C	D	E
-1.5 to -1.0	2.83 - 2.00	0.0	0.0	0.0	0.0	0.0
-1.0 to -0.5	2.00 - 1.41	0.0	0.0	0.0	0.0	0.0
-0.5 to 0.0	1.41 - 1.00	0.3	0.2	0.3	0.3	0.3
0.0 to 0.5	1.00 - 0.707	2.2	2.6	2.5	2.7	2.7
0.5 to 1.0	0.707- 0.500	12.9	12.7	12.6	12.9	13.5
1.0 to 1.5	0.500- 0.354	34.8	34.7	35.4	34.4	35.2
1.5 to 2.0	0.354- 0.250	42.3	41.8	41.5	41.9	40.9
2.0 to 2.5	0.250- 0.177	5.1	5.7	5.3	5.3	5.2
2.5 to 3.0	0.177- 0.125	2.1	2.0	2.1	2.1	1.9
3.0 to 3.5	0.125- 0.088	0.3	0.4	0.3	0.3	0.3
3.5 to 4.0	0.088- 0.0625	0.0	0.0	0.0	0.0	0.0

The sieves being used, with the exception of the 177 micron size, fall within the range of tolerances given by the ASTM for permissible calibrated size opening vs nominal (stated) size openings. Results of the calibration are given in Table 3.

Table 3

Sieve size in microns	Calibrated Sizes Stockman	Calibrated Sizes Hofmann
1000	1000	1000
710	719	719
500	501	500
350	368	361
250	257	253
177	198	197
125	125	124
88	86	86
62	66	66

2.3 Interpretation

The weight lost by 600 miles of grain bed transport cannot, in the case evaluated, be detected by comparative sieving. The percent loss by abrasion is of the same order as the percent variation due to inherent sieving errors.

Even though the nominal sieve openings are tolerably accurate (with the exception of 177 μ sieve) cognizance must be made of the effect of flatness ratio on the material retained on any one sieve. This effect probably overshadows the variations in nominal vs calibrated sizes.

3.0 Future Progress

3.1 Abrasion Tests

Anastasia formation rock fragments will be tested in the coming month.

3.2 Analyses of Dune Samples

The 99 dune samples will be sieved and the information needed for the Inman parameters computer program will be obtained.

3.3 Carbon-14 Activity

Determination of C_{14} activity of four beach samples will be completed.

APPENDIX D

Quarterly Progress Report No. 4
1 November 1964 to 1 February 1965

to

Coastal Engineering Research Center
U. S. Army Corps of Engineers
DA-49-055-CIV-ENG 64-8

1.0 INTRODUCTION

1.1 Purpose of the Project

The purpose of this program is to seek answers in the following questions in order to design a remedial program of natural or artificial beach nourishment.

1. Is the present beach shell composed of recent shell or old shell or of both and in what proportion?

2. If new shell, at what rate is the shell coming into existence to replenish the beaches?

3. If old shell, is the source offshore? from the eroded beach face? or from the weathering of the coquina?

4. In what way is the beach shell lost to the beaches at the present high rate? by dissolving into the sea water? by grinding into powder? or by moving offshore?

5. Is there any indication that the silica sand component of the beach tends to remain on the beach longer than the shell?

1.2 Review of Previous Work

A series of beach sand samples, collected from Jacksonville, Florida to Miami Beach, Florida at ten mile intervals where practicable, were sieved. The carbonate and insoluble weights were obtained for each siene separate and the data programmed for weight percentages and Inman sediment parameters.

A series of dune cores from Miami Beach to False Cape, Cape Kennedy were analyzed in the same manner as the beach sands. This data is also being programmed.

Random samples of Anastasia rock were dissolved in acid and the insolubles were treated in the same manner as the beach sands and dune sands.

Appendix D(contd.)

Abrasion tests of shell material and rocks with different degrees of cementation were completed.

Four beach sand samples were submitted for radiocarbon analysis. Three dates have been obtained.

Sieving tests for reproducibility of results and calibration of sienes were completed.

1.3 Fourth Quarterly Progress Report

Section two of this fourth quarterly report will describe progress not previously reported.

2.0 PROGRESS

2.1 General

Anastasia (Pleistocene) rocks were abraded. Three C_{14} dates were obtained.

2.2 Results

Weight losses of four Anastasia rocks, are shown below for a distance travelled of 193 miles. Most friable to least friable is read from left to right. Weights are in grams.

Original weight:	6.1023	8.1735	7.6620	10.1710
Abraded weight:	4.6197	6.5708	6.9620	9.6424
Weight loss:	1.4831	1.6027	0.7000	0.5286
% loss:	24.3	19.6	9.1	5.2
Miles of travel per % loss:	7.9	9.8	21.2	37.1

The three C_{14} dates of beach sands are shown below.

Distance north of Miami Beach (approximate)	Date (years B.P.)
135 miles	13,900 ± 250
42 miles	8,000 ± 125
25 miles	8,320 ± 110

2.3 Interpretation

All data is now being integrated into a final report, for which a three months' extension has been granted. Report is due April 30, 1965.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R&D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*

INSTITUTE OF MARINE SCIENCES

2a. REPORT SECURITY CLASSIFICATION

2b. GROUP

3. REPORT TITLE THE ROLE OF SHELL MATERIAL IN THE NATURAL SAND REPLENISHMENT CYCLE OF THE BEACH AND NEARSHORE AREA BETWEEN LAKE WORTH INLET AND THE MIAMI SHIP CHANNEL.

4. DESCRIPTIVE NOTES *(Type of report and inclusive dates)*

FINAL REPORT

5. AUTHOR(S) *(Last name, first name, initial)*

RUSNAK, GENE A., STOCKMAN, KENNETH W., AND HOFMANN, HERMANN A.

6. REPORT DATE

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10. AVAILABILITY/LIMITATION NOTICES

11. SUPPLEMENTARY NOTES

12. SPONSORING MILITARY ACTIVITY

U. S. ARMY CORPS OF ENG.

13. ABSTRACT Study made of beachface and foredune sand samples spaced at 8 mile intervals over a distance of 277 miles. Methods used in the study included grain-size, x-ray and optical mineralogy, shell assemblages, and assays of radiocarbon activity. Results show systematic increase of shell content at a rate of 0.2% per mile between Jacksonville and Miami. Experiments suggest little shell material is lost by abrasion during bed-load transport. Neither mineralogic nor paleontologic study provides a confident method for distinguishing between fresh contemporaneous shell contributions and a source of old shell deposits eroded from local substrate. Thus, paleontologic and mineralogic criteria could not be used to evaluate the fractional contribution of "new" and "old" shell to the beach replenishment cycle. Radiocarbon assays demonstrate that as little as 20% of the total shell content near Cape Kennedy is new shell, but near Miami as much as 50 to 60% of the total may be new shell contributed by an indigenous population. Inlet areas apparently show the highest contribution of new shell because of favorable environmental factors which produce high standing crops of shelled organisms. It is concluded that relatively little shell is being contributed to the northern beaches of Florida either by erosion of older deposits or by contributions from contemporaneous sources. Beaches near Miami receive comparatively little quartz sand from northern Piedmont areas and are greatly dependent upon the approximately equal contribution of shell material which is derived from erosion of local older deposits and contributed by an indigenous population of shelled organisms. The shell source obviously can not keep up with sand loss. The loss of sand from the beaches near Lake Worth to Miami may be attributed to capture by tidal inlets, although loss to deep water by spilling off the narrow shelf appears to be the principal sink.

DD FORM 1 JAN 64 1473

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Security Classification

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Beach erosion Beach replenishment Grain size analyses Radiocarbon assay Abrasion of shells						

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There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, roles, and weights is optional.

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